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Agricultural Sciences

M Burger

W Burger



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Agricultural Sciences

Grade 12

Learner's Book

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Solutions for all Agricultural Sciences Grade 12 Learner's Book

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Contents

Topic 1: Animal nutrition	1
Unit 1: The alimentary canal of ruminants and non-ruminants – functions, adaptations and description	2
Unit 2: Digestion in non-ruminants, ruminants and in the rumen	12
Unit 3: Components of feed	24
Unit 4: Digestibility of feeds – biological value, energy value and nutritive ratio	36
Unit 5: Types of feed – classification of feed, feed flow programme	50
Topic 2: Animal production	66
Unit 1: Animal production systems	67
Unit 2: Animal shelter/protection/housing – intensive systems	80
Unit 3: Behaviour and handling of farm animals	101
Topic 3: Animal reproduction	118
Unit 1: Male and female reproductive systems of cattle, and the oestrus cycle	119
Unit 2: Synchronisation of oestrus – natural mating and artificial insemination	134
Unit 3: Embryo transplantation, nuclear transfer, fertilisation and pregnancy	146
Formal assessment for Term 1	160
Unit 4: Birth/parturition and dystocia – milk production/lactation	163
Topic 4: Animal diseases and protection	173
Unit 1: Animal diseases and protection	174
Unit 2: Internal parasites/endoparasites and external parasites/ectoparasites	192
Unit 3: Plant and metallic salt poisoning	204
Topic 5: Basic agricultural genetics	217
Unit 1: Genetic concepts	218
Unit 2: The pattern of inheritance – variation and mutation	228
Unit 3: Selection – principles, methods and systems	242
Formal assessment for Term 2	254
Unit 4: Genetic modification/genetic engineering	255
Topic 6: Agricultural economics	267
Unit 1: Agricultural production factors: land and labour	268
Unit 2: Agricultural production factors: capital and management	283
Unit 3: Agricultural marketing	303

Unit 4: Agricultural marketing systems	316
Unit 5: Agricultural entrepreneurship and business planning	331
Formal assessment for Term 3	343
Mid-year examination.....	348
End-of-year examination: Paper 1	352
End-of-year examination: Paper 2	357
Index	362

Animal nutrition

What you will learn about in this topic

- a comparison of the external structure of the alimentary canal between a ruminant and a non-ruminant
- functions and adaptations of various structures of the alimentary canal
- description of the internal structure of the rumen, reticulum, omasum, abomasums and small intestines
- digestion in non-ruminants
- digestion in ruminants
- digestion in the rumen
- components of feed
- digestibility of feeds
- quality of feed (biological value of proteins)
- energy value of feed
- nutritive ratio
- types of feed
- subdivision of feeds
- supplements to rations
- planning a feed flow programme



Let's talk about this topic

Animal husbandry is the keeping of domestic animals for the production of products that can be consumed or sold. These products can be mutton from sheep, beef from cattle, pork from pigs or broilers from poultry. They can also be wool from sheep, mohair from goats, feathers from poultry, hides from cattle, skins from sheep, or milk from cows and goats. These products are all affected by how well you feed your animals. This is known as animal nutrition. The pulling power of draught horses, donkeys and oxen is also affected by the animals' nutrition.

The better or more 'optimal' the nutrition is, the more prosperous the farming enterprise will be. Optimal means that the animal receives just enough of the nutrients needed for it to grow and produce products such as milk and hair or wool. We refer to the optimal ration of an animal per day as a balanced ration (of nutrients).



Unit 1: The alimentary canal of ruminants and non-ruminants – functions, adaptations and description

What you will learn about in this unit

- a comparison between the external structure of the alimentary canal of ruminants and non-ruminants
- the functions and adaptations of the structures that make up the alimentary canal
- a description of the internal structure of the rumen, reticulum, omasum, abomasum and small intestine

Let's talk about this unit

Different animals have different alimentary canals. These differences are a result of adaptations to different ways of feeding. Ruminants have adapted to roughages consisting of crude fibre. Ruminants are able to survive on plant fibre because their alimentary canals include a bag-like **fermentation** organ. This organ is called the rumen. All ruminants have a rumen that enables them to digest crude fibre. Animals that do not have a rumen are called non-ruminants. Some non-ruminants are able to partially digest plant fibres such as **cellulose** or **lignin**. However, there are other non-ruminants, such as humans, that are unable to digest plant fibre at all.

What do I know already?



You should know that pigs cannot digest crude fibre such as grasses. You should also know that cows, sheep and goats live on grasses, shrubs and bushes – i.e. plant fibre. Cattle, sheep and goats are ruminants, whereas pigs are non-ruminants.



- List the kinds of food that you eat daily. How many of these foods consist of crude fibre?
- Why can humans eat raw carrots and raw cabbage, but not raw kikuyu-grass?

Word bank



assembly plant: a place where things are created and assembled, such as a motor-car factory
caecum: a pouch or sac at the beginning of the large intestine; also called a blind gut
cellulose: a highly insoluble organic substance that forms part of the solid framework of plants

fermentation:	a chemical reaction whereby an organic molecule is broken down into simpler substances; this process releases carbon dioxide and other gases
lignin:	an organic substance forming an essential part of wood
oesophagus:	an organ present in all vertebrates; consists of a muscular tube through which food passes from the mouth to the stomach
omnivores:	animals, such as pigs and humans, that can live on both plants and animals
peristalsis:	a contraction and relaxation of muscles, which moves in a wave down a muscular tube
sphincter:	a ring-like muscle that tightens or relaxes to let material pass through

What I still need to know



Raw foodstuffs are all digested inside the alimentary canal. It is in this canal that the food is broken down by enzymes (digested) and changed into soluble nutrients that can be absorbed into the bloodstream. Once in the bloodstream, these nutrients are distributed to all the cells of the body, where they are used for energy and growth, and for producing new cells.

Humans cannot digest the crude fibre on which livestock is fed, which is the reason why, as non-ruminants, humans rear ruminant livestock that can convert crude fibre into foods such as meat and milk. This is called the economic conversion of plant material into animal products. It is therefore the aim of the livestock farmer to make a profit from this conversion by selling the products, for example, meat, for more than he spent to produce that product. To maximise this profit, the farmer must farm in a scientifically correct way.

A comparison between the external structure of the alimentary canal of ruminants and non-ruminants

Ruminants have a complex digestive system consisting of a multi-chambered stomach where fibrous material is circulated and broken down. The alimentary canal of non-ruminants is far simpler, but lacks the ability to break down fibrous foods.

The alimentary canal of ruminants (for example, cattle and sheep)

The capacity of the stomach of a cattle is between 150 and 200 l. Its stomach is divided into four compartments. They are:

- the rumen (or large stomach)
- the reticulum (or net stomach, also called honeycomb)
- the omasum (or leaf stomach)
- the abomasum (or true stomach, also known as the milk stomach).

The small intestine in cattle is about 45 m long and is attached to the end of the abomasum, which is the last compartment of the stomach. The small intestine in turn is connected to the large intestine. The large intestine is an elongated 'bag' about 11 m in length. It consists of the **cardia**, the colon and the rectum, and it ends in the anus. Figure 1.1 on the next page shows a diagram of the alimentary canal of a cow.

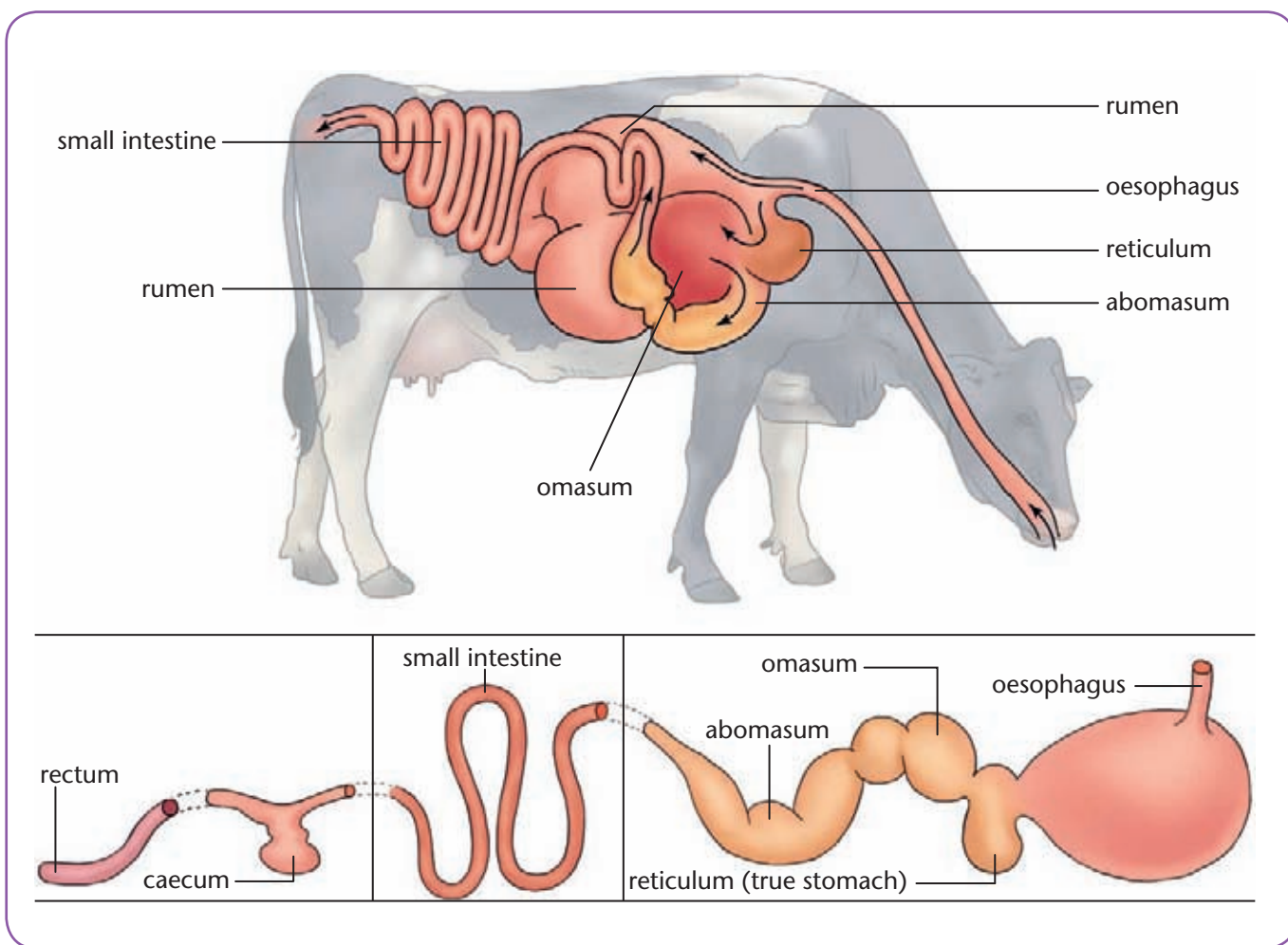


Figure 1.1: The alimentary canal of a cow (ruminant)

The capacity of the stomach of a sheep is much smaller than that of a cattle – about 50 l – but it is similar in that it also has four components and has the same structure and function.

The alimentary canal of non-ruminants (for example, pigs and fowls)

The alimentary canal of a non-ruminant has a much smaller capacity (relative to its body size) than that of a ruminant. This is because the structure is simpler and the functions are different. The large rumen of the ruminant is the most distinctive difference, and its functions are unique to ruminants.

The alimentary canal of a pig

The pig has a comparatively simple alimentary canal. It is very similar to that of a human being. The stomach of the pig has a capacity of 8 l. It consists of three parts:

- the cardiac
- the fundus
- the pylorus.

The small intestine of a pig is connected to the end of the pyloric parts. It is a long, narrow tube of about 15 m in length. It is subdivided into three parts:

- the duodenum
- the jejunum
- the ileum.

The large intestine comes behind the small intestine. The large intestine is much shorter than the small intestine – it is only 2 m long. The large intestine consists of the caecum, the colon and the rectum, and ends in the anus (see Figure 1.2).

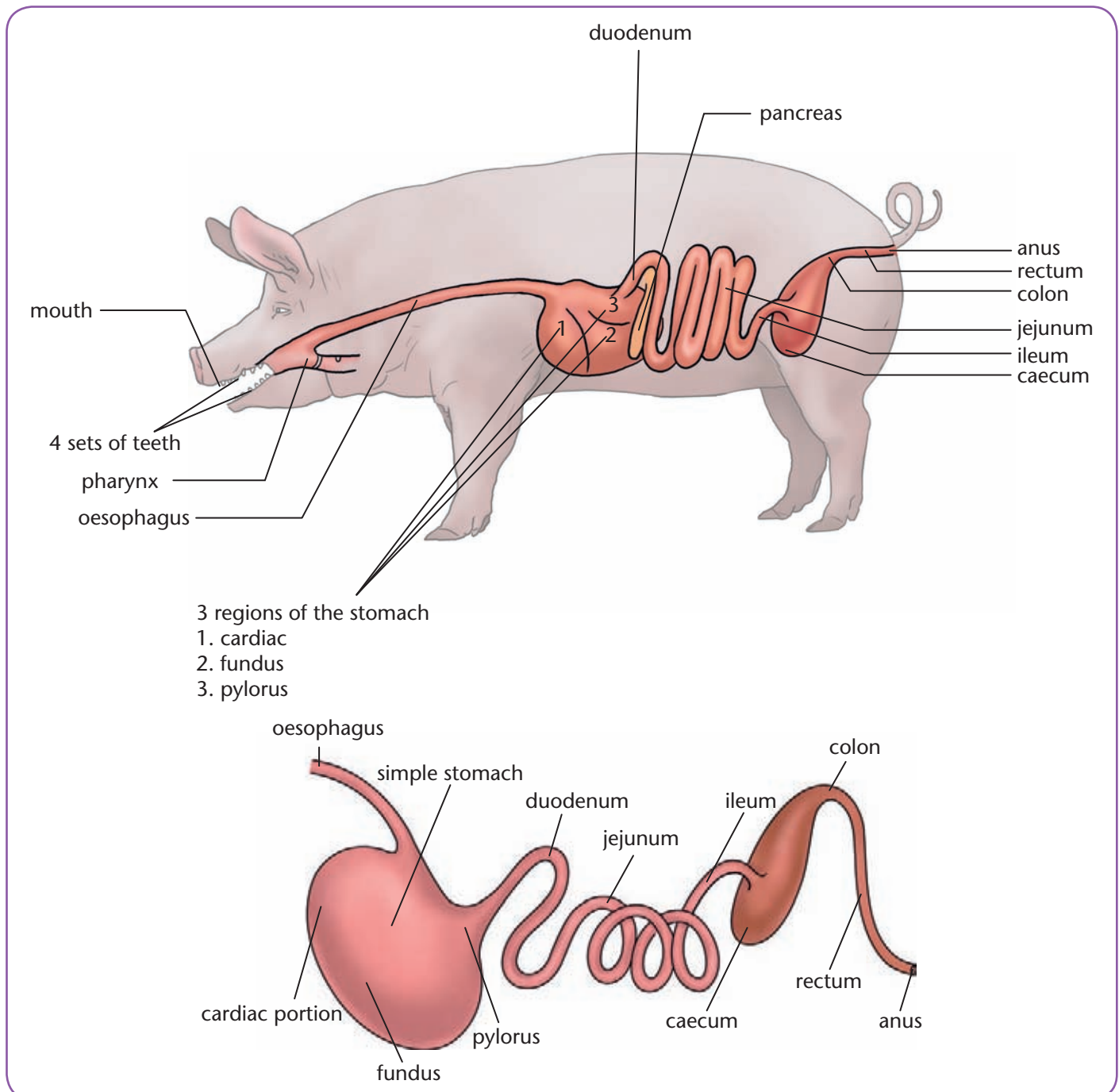


Figure 1.2: The alimentary canal of a pig (non-ruminant)



The alimentary canal of a fowl

Fowls have a different **oesophagus** to pigs and cattle. Fowls have a soft, bag-like structure known as the crop. Food is stored in the crop. A fowl's stomach consists of:

- the gland stomach
- the muscle stomach.

The digestive juices are secreted in the gland stomach. The food is ground in the muscle stomach. After the muscle stomach is the small intestine. There are two blind guts (caeca) where the small intestine joins the large intestine (see Figure 1.3). After the rectum is a large cloaca. The cloaca is the external opening of both the digestive system and the reproductive system.

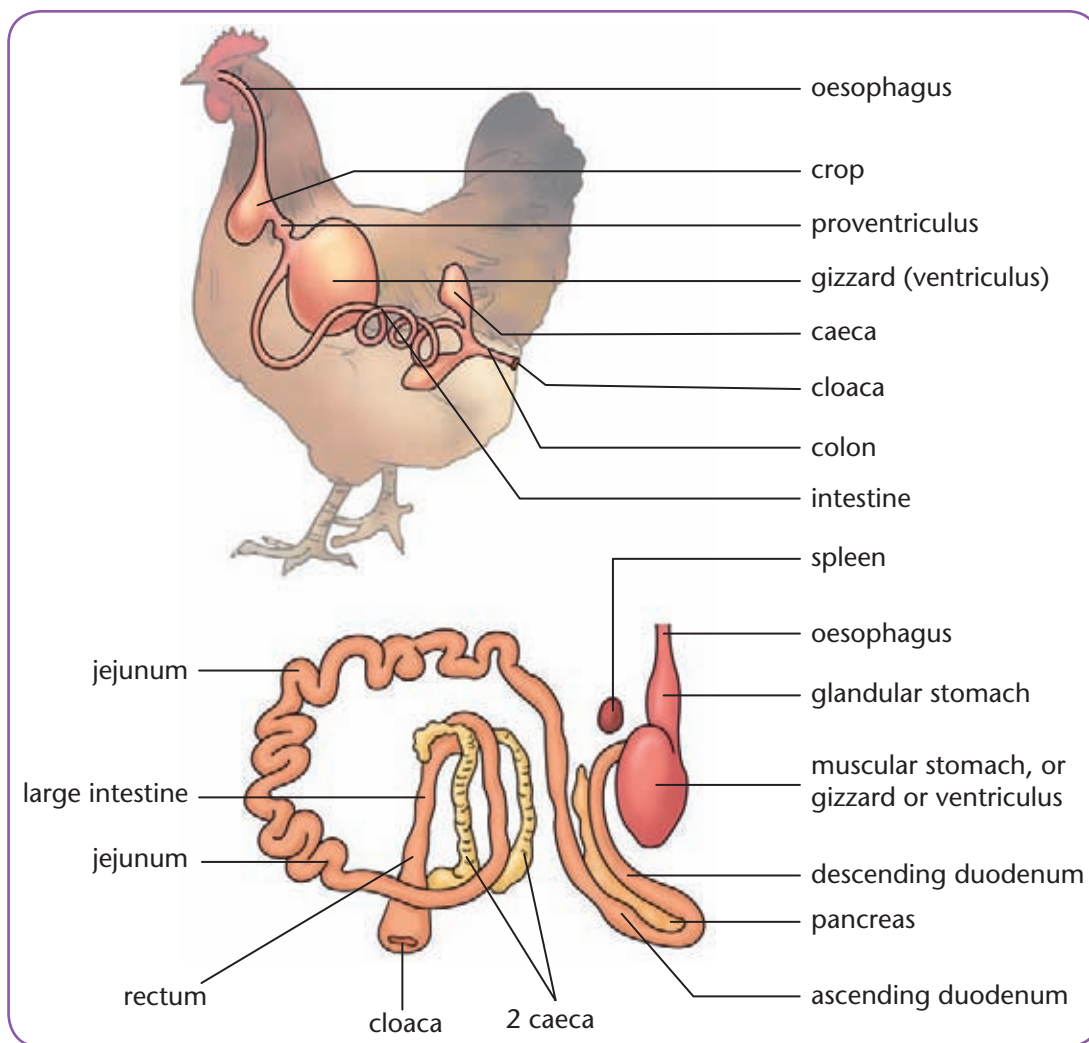


Figure 1.3: The alimentary canal of a fowl (non-ruminant)

The functions and adaptations of the various structures of the alimentary canal

The alimentary canal of all animals functions like a conveyor belt in an **assembly plant**. As the food travels down the canal, different structures give different inputs and the food is progressively broken down, refined and digested until only waste products remain.

Functions and adaptations of the various structures of the alimentary canal of a ruminant (for example, a cattle)

Cows have broad, thick and immovable lips. The upper jaw has a hard cushion and no incisor teeth. A long, muscular, very movable tongue draws plant material into the mouth. The plant material is then pinched between the lower incisors and the cushion in the upper jaw, and torn off with a jerk. Cattle have three pairs of salivary glands in their mouths, which secrete large quantities of saliva.

As mentioned earlier, cattle have a stomach capacity of between 150 to 200 ℓ and the stomach is divided into four main parts. The rumen is the largest part. It makes up about 80% of the stomach's capacity. The reticulum makes up 5%, the omasum 7% and the abomasum 8%. The first three parts are where the food is stored and moistened. Fermentation also takes place inside these structures. The fourth part (the abomasum) is where digestion starts.

The first two parts of the stomach of young calves take some time to develop, so milk flows through a tubular groove straight into the omasum. As soon as the calf starts to eat solid food, the rumen and the reticulum expand until they make up 85% of the total stomach capacity of an adult cow. Figure 1.4 shows how a calf's stomach changes as it grows older.

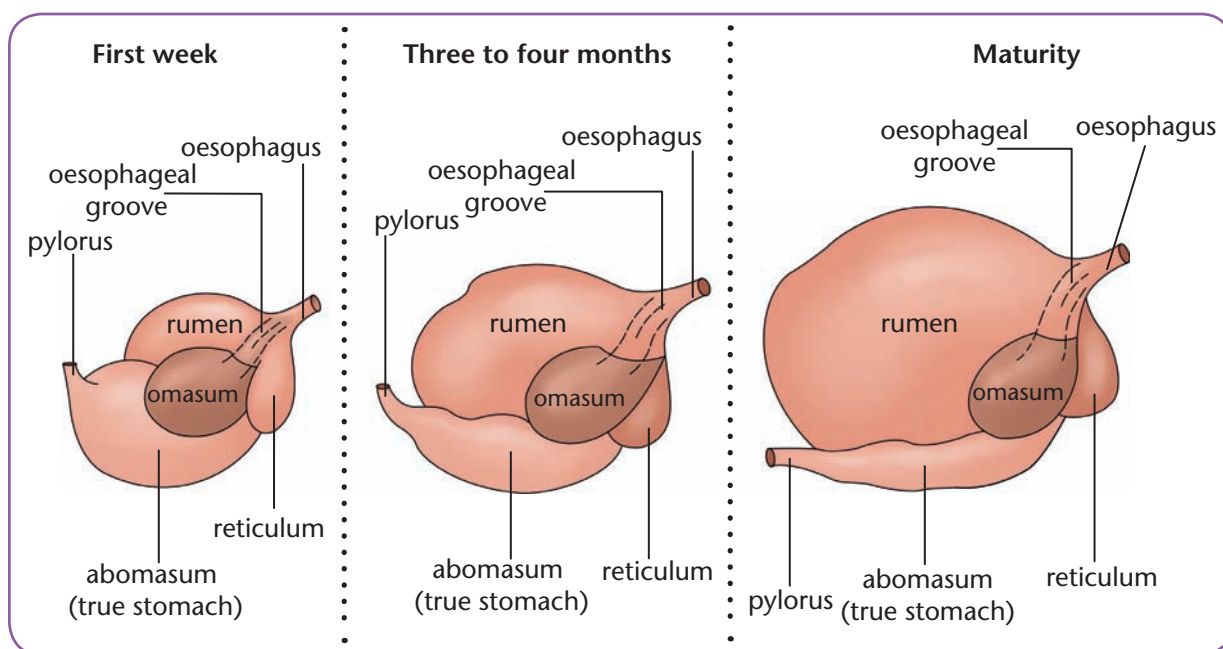


Figure 1.4: The alimentary canal of a developing calf and an adult cow

The process of digestion, which is started in the abomasum, is completed in the small intestine. The intestine does this by secreting different enzymes from glands. These enzymes break down the food into increasingly smaller particles. Once the food is small enough, the nutrients can be absorbed through the wall of the intestine. The nutrients then make their way into the bloodstream where they are distributed throughout the body.

No digestion takes place in the large intestine. The large intestine is a storage place for the undigested remains of food, i.e. the faeces. Water is absorbed back into the body from the undigested food remains in the large intestine.



Functions and adaptations of the various structures of the alimentary canal of a non-ruminant (for example, a chicken)

A chicken does not have lips or teeth. Instead, it has a beak and a small, pointed tongue. The tongue has limited mobility. A chicken has salivary glands that secrete saliva to lubricate food and to start the digestion process. It has a very small pharynx (or throat) and an oesophagus. The oesophagus has a soft, bag-like enlargement called the crop. Food is moistened and softened in the crop before it enters the stomach. The stomach of the chicken consists of two completely separate parts. The first is a soft stomach with many glands. It is called the gland stomach. Digestive juices are secreted in the gland stomach. The gland stomach is similar to the stomach of a mammal.

The muscle stomach comes after the gland stomach. It has thick walls and is approximately 50 mm in diameter. Food is ground up in the muscle stomach. To do this, chickens ingest small rocks as they (like most birds) have no teeth for grinding.

After the stomach is the small intestine. Two blind guts are found where the small intestine joins the rectum. These blind guts, or caeca, create additional surface area where water is absorbed from the faeces back into the body. The rectum ends in a large cloaca in which both the alimentary canal and the urogenital systems end.

Adaptations in ruminants and non-ruminants: a comparison

The feed of ruminants, be it from the veld or in the form of hay, mainly comprises roughages with a low concentration of nutrients, such as lipids, protein, vitamins and minerals.

Even the carbohydrates are in the form of bulky lignin, cellulose and hemi-cellulose. As a result, ruminants are adapted to digest this crude fibre to obtain the nutrients.

Digesting plant fibre is largely a fermenting process caused by micro-organisms. Fermentation also requires a lot of space. This explains why the rumen is so large, and why it contains the micro-organisms that are able to ferment crude fibre.

In comparison, a non-ruminant has a stomach more like ours. This stomach can be compared with the abomasum of a ruminant. Here enzymes are secreted that are able to digest more concentrated food. More concentrated food contains less plant fibre and more nutrients.

The stomach of the non-ruminant is able to hold the food for only a relatively short time ($\pm$ four hours). After this, the partially digested food (chyme) moves into the small intestine where the actual digestion of food and absorption of nutrients take place. The stomach of the non-ruminant is thus relatively small compared with a ruminant.

Some non-ruminant animals, such as horses and fowls are, however, able to digest crude plant fibre. The alimentary canal of the horse has an enlargement (the caecum) in which fermentation takes place – allowing the horse, though not a ruminant, to feed on roughages. Fowls have a crop in which crude fibre foods are softened, followed by the muscular stomach that helps grind the food.

Description of the internal structure of the alimentary canal of a ruminant

The alimentary canal of the ruminant consists of six parts, namely the rumen, reticulum, omasum, abomasum, small intestine and large intestine. This section deals with the internal structure of these parts.

The rumen

The capacity of the rumen varies according to the size of the animal. The rumen is lined with densely packed, finger-like protrusions called papillae. No enzymes are secreted in the rumen. It is a fermentation vessel. The rumen is responsible for changing the food mass into a form that can be digested by the animal. This change occurs through fermentation by micro-organisms that have a symbiotic relationship with the host animal.

The reticulum

The reticulum is responsible for mixing the food. It does this by constantly contracting its muscular cell walls. It does not secrete any digestive enzymes or juices. The wall of the reticulum contracts constantly so that the food is mixed. A tubular groove stretches from the oesophagus through the rumen and reticulum into the abomasum. This is a very important structure for young animals, as you will see later when you learn about the development of the digestive system of young animals.

The omasum

The omasum is responsible for grinding down food particles that are too big to be digested in the abomasum. Food is also dried out in the omasum. The food is ground down by powerful, muscular folds. There are also leaf-shaped protrusions or lamellae in the omasum. These protrusions prevent coarse food from entering the abomasum. There are four different kinds:

- primary lamellae
- secondary lamellae
- tertiary lamellae
- quaternary lamellae.

Primary leaves are the largest while the quaternary are the smallest.

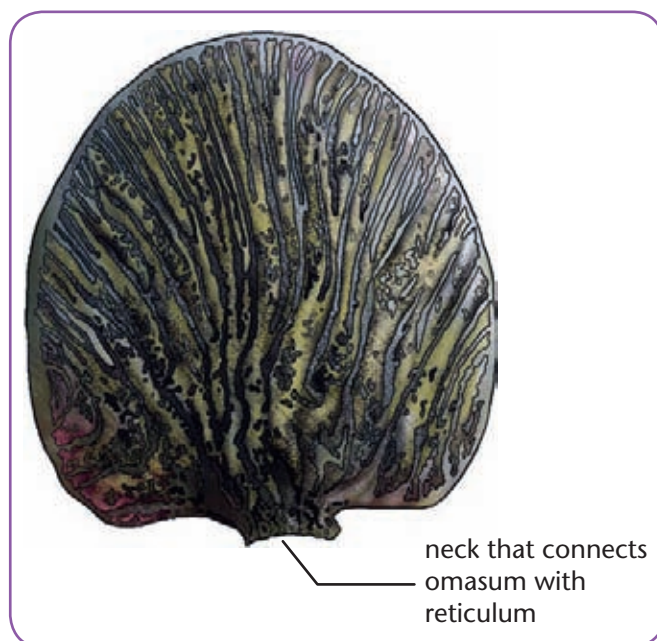


Figure 1.5: Cross-section of omasum illustrating lamellae

The abomasum

The abomasum starts off the digestive process.

Digestive juices, called gastric juices, are secreted here.

A **sphincter** muscle called the pylorus joins the duodenum (the first section of the small intestine) and the abomasum. The pylorus regulates the flow of half-digested food (called chyme) into the duodenum. The abomasum of the ruminant can be compared with the stomach of the non-ruminant.

The small intestine

The small intestine is the main region for digestion and absorption in the alimentary canal. The wall of the small intestine is made up of muscles. These muscles make **peristalsis** possible. It is here that the chemical substances that were derived from the feed enter into the bloodstream. Once in the bloodstream, the chemicals are used for energy or converted into living tissue. The absorption surface of the intestinal wall is covered in folds. The surface is further enlarged by small finger-like protrusions named villi. Each of these



contains capillary blood vessels and a central lymph vessel (see Figure 1.6). A blood vessel from the aorta supplies blood to the villi in the wall of the small intestine.

The portal vein system transports the blood, which is rich in nutrients, to the liver. Tiny muscles are found in the villi, which keep them in constant motion. A large number of small glands are found between the villi. These glands are called the glands of Lieberkühn. They secrete a juice that contains digestive enzymes.

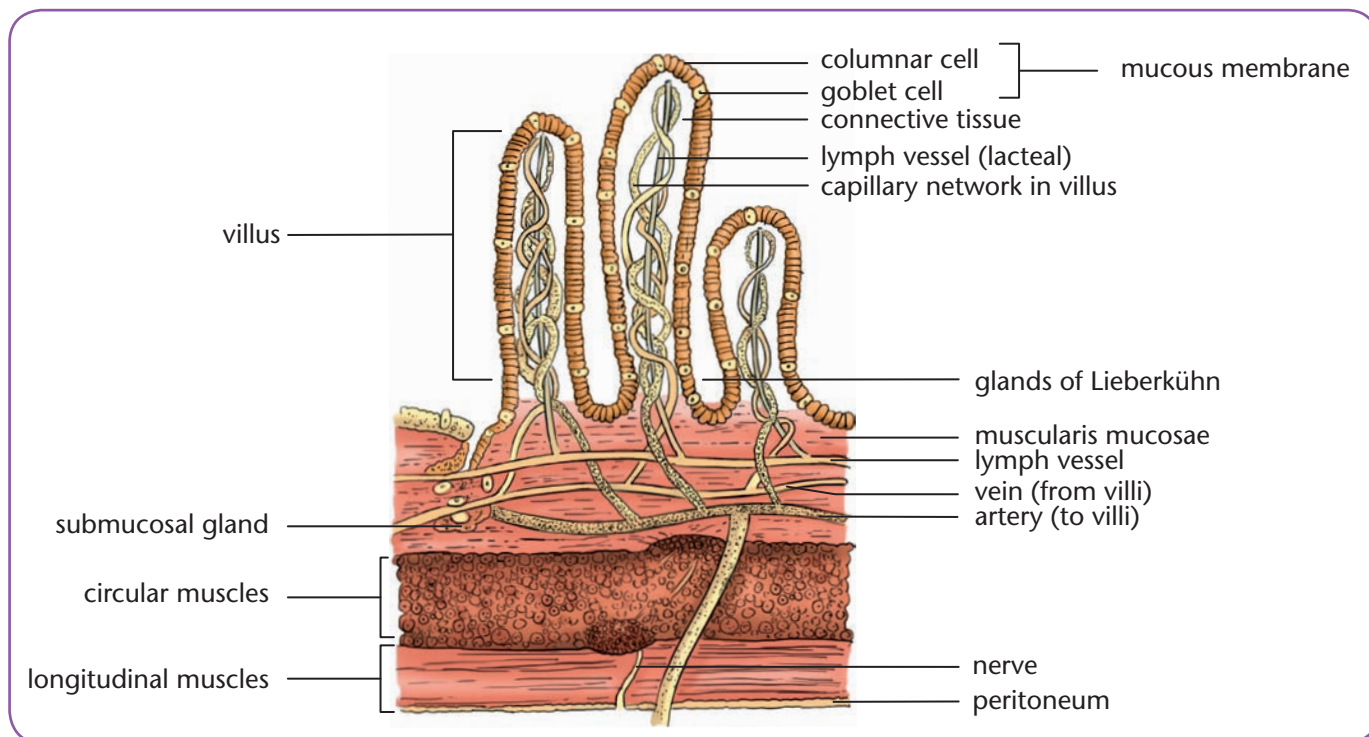


Figure 1.6: Longitudinal section through the villus and mucous membrane of the small intestine

Large intestine (the colon)

The large intestine joins the small intestine. It consists of the **caecum**, the colon and rectum, and it ends in the anus.

Classroom activity 1

Work with a partner.

- 1 Why is a pig unable to digest crude fibre?
- 2 Which gases are produced in the alimentary canal which may cause a ruminant to bloat?
- 3 Why can it be fatal for an animal when it eats a small piece of baling wire?
- 4 The longer a piece of cooked potato or sweetcorn pips are chewed, the sweeter they become. Why?
- 5 Give the correct term for each of the following:
 - a) The alternating contracting and relaxing of the circular muscles in the alimentary canal.
 - b) The short, muscular tube which gives passage to both food and air.
 - c) In the place of teeth in the upper jaw of a ruminant.
 - d) The grinding teeth of a chicken.

- e) A hormone which controls the sugar content of blood.
- f) Glands which secrete succus entericus.
- g) An enzyme which digests fats.
- h) A chain-like polysaccharide.
- i) Function as catalysts in the body.
- j) Small finger-like extensions in the small intestine.

- 6 Obtain a gall bladder from the abattoir, or when a farm animal is slaughtered in your vicinity. Half fill a test tube with bile. Add a few drops of olive oil and shake well. You will notice that the oil breaks up into very fine drops which are suspended, i.e. it forms a permanent emulsion. What is your conclusion with regard to bile?

Homework activity 1

Work alone.

Answer these questions to show your understanding of the alimentary canals of cattle, pigs and fowls. Use the keywords in brackets to help you answer the questions.

- 1 Why do ruminants, for example cattle, have such big stomachs, especially the rumen part? (fibrous plant feed, micro-organisms)
- 2 Describe the stomach of a pig. (non-ruminant **omnivore**)
- 3 Ruminants are able to store food in their rumen for a number of hours after they stop grazing. How do you think this adaptation helps ruminants in the wild?
- 4 Fowls have an enlargement in the alimentary canal called the crop, as well as a gland stomach and a muscle stomach. How do these structures help chickens digest their food? (whole grain/no teeth)
- 5 Which livestock animal plays the main role in forming a bridge between fibre such as cellulose and lignin, and edible food (for humans), such as milk, meat and eggs?

Extra practice 1

Work in a group.

The functions and names of the basic parts of the alimentary canal and additional digestive organs are summarised below. Fill in the missing names. You have not learnt about all of these organs yet, so you will have to use your prior knowledge to complete the table.

	Parts of the alimentary canal	Additional organs
Preparation of food	Mouth, throat and _____	Lips, teeth and _____ glands
Digestion and absorption of food	Stomach and small intestine (ileum and _____)	Liver and _____
Excretion of waste products	Rectum and _____	



Unit 2: Digestion in non-ruminants, ruminants and in the rumen

What you will learn about in this unit

- **digestion in non-ruminants**
 - a brief explanation of the intake of feed
 - the process of digestion in the mouth, stomach, small intestine and large intestine (colon):
 - mechanical digestion
 - chemical digestion (enzymes)
 - the functions of the accessory glands such as the liver, pancreas and intestinal glands
- **digestion in ruminants**
 - terminology: rumination, regurgitation, peristalsis
 - explanation of the intake of food, chewing of the cud
 - the differences between a mature ruminant and a young ruminant based on the four stomach compartments (size, functionality, etc.)
- **digestion in the rumen**
 - concepts: rumen microbes
 - the different types of rumen microbes
 - important requirements for normal functioning of rumen microbes/micro-organisms
 - the functions of the rumen microbes
 - the absorption of food in the rumen directly by osmosis and diffusion into the bloodstream

Let's talk about this unit

Before any foodstuff can be absorbed into the bloodstream and be of any benefit to the animal, it has to be refined. In other words, it must be digested. Insoluble molecules need to be converted into soluble molecules. For example, carbohydrates such as starch cannot be absorbed by the body. They need to be broken down into simple sugars, i.e. into monosaccharides such as glucose. Proteins also need to be broken down into smaller amino acids. All of this takes place during digestion. Processes of digestion in the non-ruminant differ greatly from those in the ruminant.

What do I know already?



Human evolution has depended to a large extent on our ability to overcome the problems of not being ruminants, and to use various methods to consume foodstuffs of all kinds. Think of two methods that human beings use to overcome this difficulty.

Check myself

How does cooking affect the fibrous material in our diets? Name three vegetables that we cannot eat raw and three that we can, and decide what the difference between them is.

Word bank



chemical digestion:	the chemical changes of food which take place in the animal stomach and bowels caused by enzymes (catalysts) so that it can be used as nutrition
circumference:	distance around an object (for example, around a circle)
diffusion:	movement of molecules of a certain material from high to low concentrations of the molecules
mechanical digestion:	breaking down of food through physical actions, such as turning the food or chewing it
osmosis:	the movement of water molecules from a region of higher concentration to a region of lower concentration through a semi-permeable membrane
silage:	plant matter (grain stalks, lucerne hay) that has undergone partial fermentation in storage under anaerobic (oxygen free) conditions, in a silo or bunker; chop it and add molasses (the initial fermentation process makes the plant matter easier for ruminants to digest)
symbiosis:	a close relationship or association between two organisms, which usually benefits both

What I still need to know



Digestion in non-ruminants (for example, the pig)

Digestion in non-ruminants is very similar to our own digestion. We are also non-ruminants. We are also omnivores, meaning that we eat both plant and animal matter. If you have learnt about human digestion in Life Sciences, you will find this section easy to understand.

Food intake by non-ruminants and digestion in the mouth

Mechanical digestion takes place in the mouth. By chewing, an animal breaks down the large bits of food into smaller particles. The teeth and tongue play a vital role in this. The food particles are also mixed with saliva. Saliva acts as a lubricant. Saliva is a colourless alkaline liquid that is secreted when the animal sees, smells or tastes its food. The quantity secreted is largely determined by the moisture content of the food. Saliva contains the enzyme amylase as well as inorganic salts. Amylase changes starch into maltose. Very little digestion takes place in the mouth. This is because the food is swallowed very quickly and moves through to the oesophagus.



Functions of the tongue in food intake

- It acts as a taste organ by means of taste buds.
- It helps with the chewing process because it pushes food towards the teeth.
- It helps with the process of swallowing.
- It helps mix the food with saliva to form a bolus (a round mass of food).
- The tongue plays a role in determining the presence of foreign objects in the feed.

Functions of saliva in food intake

- It moistens the food so that it can be easily swallowed.
- It serves as a solvent for food in the process of tasting.
- It lubricates the mouth and protects the inner walls by keeping them moist.
- It plays a role as a binding agent to hold food particles together in the form of a compact bolus.

Digestion in the oesophagus (or gullet)

No physical digestion takes place in the oesophagus and no digestive juices are secreted here. The enzyme action of amylase is continued in the oesophagus. **Chemical digestion** begins with the action of amylase, and continues as the food moves through the digestive canal. Food moves through the oesophagus and the rest of the digestive canal by peristalsis.

Peristalsis is the alternating contracting and relaxing of circular muscles in the alimentary canal. The **circumference** of the gullet is enlarged at one end and narrowed at the other. A wave of contractions moves down the oesophagus, pushing the food down with it. The bolus is then transported from the upper end of the oesophagus into the stomach. As soon as the bolus enters the oesophagus, the circular muscles behind the bolus contract and those ahead of the bolus relax – in this way the bolus is forced down the oesophagus. Reverse peristalsis may also occur when vomiting takes place.

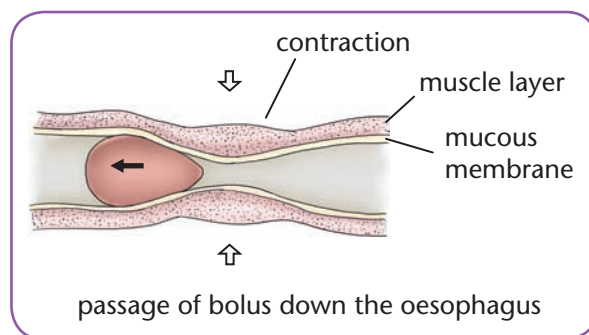


Figure 1.7: The passage of a bolus down the oesophagus – the arrow indicates the direction the food moves in due to peristalsis

Digestion in the stomach

The stomach of the pig is lined with a thick membrane. It contains a large number of small glands that secrete gastric juice. This secretion is caused by the smell of food as well as the hormone gastrin. Gastric juice consists of 0.2% hydrochloric acid, rennin and pepsinogen. Pepsinogen is the precursor of the enzyme pepsin. The concentration of hydrochloric acid in the stomach secretion is sufficient to lower the pH of the stomach contents to a level of 2.0. At this pH, pepsinogen is activated and changes into the enzyme pepsin. The stomach acid is also required as a medium for the enzymes to begin working.

When food enters the stomach the pyloric valve closes and gastric juice is secreted. The action of the amylase continues for some time on the inside of the bolus. As a result of the churning movements of the stomach wall, the food is further broken down and mixed with gastric juices. When the food is fine enough and well mixed with the gastric juice, the pylorus opens and the stomach content (now called the chymus) is forced into the duodenum by peristaltic movements.

The enzyme rennin (also called chymosin) causes milk to coagulate by changing the soluble caseinogens of milk into the insoluble protein, casein, which is digestible by calves. The enzyme pepsin partially digests proteins.

Functions of hydrochloric acid (HCl) in food digestion

- It is antiseptic and so prevents the food from rotting.
- It activates the enzyme precursor pepsinogen, which changes to the digestive enzyme pepsin.
- It neutralises the alkaline medium of the saliva.
- It creates an acidic medium for the action of the rennin and pepsin.
- It changes the polysaccharide sucrose to the monosaccharide glucose and fructose.

Digestion in the small intestine

As a result of digestion in the stomach, the food is changed to an acid, semi-liquid mass called chymus. In the duodenum, the chymus is converted into an alkaline mixture by bile, pancreatic and duodenal juices. The enzyme action of pepsin and the digestion of proteins stop. In this part of the alimentary canal, all food molecules have been chemically changed so that they are small enough to be absorbed into the bloodstream. The food is pushed forward through the small intestine by peristalsis. In this process, the food is further mixed with the digestive juices that contain another range of enzymes.

Digestion in the large intestine or colon

The small intestine absorbs all the end products of digestion. These are mainly undigested cellulose, hemicellulose and lignin that move through the colon. The colon does not secrete any digestive enzymes. Excess water is absorbed from the undigested food in the colon back into the body. This makes the waste products more solid, and helps to conserve water in the body.

Undigested food remains are fermented by bacteria in the colon. This leads to gas formation. The rectum is normally empty and, when it becomes stretched by the presence of faeces, it causes a desire in the animal to empty the contents of its bowel, i.e. to defecate. When the muscles relax, the faeces can be excreted. The faeces consist mainly of water (74%), undigested food remains, dead tissue from the alimentary canal, mineral salts and bacterial waste products.

Functions of the accessory glands

Accessory glands (or ductless glands) are also responsible for the secretion of enzymes. You have already learnt about many of the enzymes involved in digestion. Enzymes act as catalysts in the body, which means that they speed up reactions without changing their composition. For example, the enzyme trypsin breaks down the macro-molecules of proteins into peptones, which are short-chain protein molecules. The following accessory glands contribute to the process of digestion: the liver, the pancreas and the glands of Lieberkühn.

The liver

The liver secretes bile. Bile is a bitter, yellow to green liquid. It is a mixture consisting of bile salts, bile pigments and phospholipids. Although it contains no enzymes, bile plays an important part in the digestive process. It is continuously produced in the liver cells but is only required when the chymus arrives. It is, therefore, stored by the gall bladder until it is needed. The gall bladder releases the bile into the duodenum. This process is controlled by hormones.



Functions of bile

- Bile neutralises the chymus coming from the stomach.
- It creates an alkaline medium, which activates the enzyme lipase, which breaks down fats.
- It helps to physically break up fat in the alimentary canal. This is called emulsification, the breaking down of fats into small fat droplets in suspension. This allows lipase to work better.
- Bile salts encourage peristalsis in the alimentary canal.
- Bile salts improve the absorption of fatty acids and glycerol, a compound that can be converted into sucrose by the liver.
- Bile also helps with the absorption of fat-soluble vitamins A, D, K and E.
- Bile is antiseptic and therefore counteracts putrefaction in the alimentary canal.

Excess bile is re-absorbed in the last section of the alimentary canal, and some of it is excreted with the faeces.

The pancreas

The pancreas secretes pancreatic juice. This is an alkaline liquid. It contains enzymes, namely amylase, lipase, trypsin and chymotrypsin. The secretion of pancreatic juice is controlled by hormones.

Functions of pancreatic juice

- The enzyme lipase changes fat to glycerol and fatty acids.
- Amylase changes glycogen and starch to dextrin, maltose and glucose.
- Trypsin and chymotrypsin break down proteoses, proteins and peptones to peptides. A peptide is a simple protein.

The glands of Lieberkühn (intestinal glands)

The glands of Lieberkühn secrete succus entericus. This is a clear, slimy liquid that is slightly alkaline. Succus entericus contains the enzymes amylase, lipase, enterokinase and aminopeptidase, which break down protein. It also contains sucrase, maltase and lactase, which break down sugars. This secretion is released when the mucous membrane is stimulated by the presence of food. It is also stimulated by the hormone enterocrinin. Enterocrinin is secreted by the liver, moves through the bile tube and into the small intestine.

Functions of succus entericus

- The enzyme enterokinase changes tripsinogen to the enzyme trypsin.
- The lipase changes emulsified fats to glycerol and fatty acids.
- Sucrase, maltase and lactase change disaccharides to monosaccharides:
 - sucrase changes sucrose to glucose and fructose
 - maltase changes maltose to glucose
 - lactase changes lactose to glucose and galactose, a type of sugar less sweet than glucose.

Digestion in ruminants (for example, cattle)

Terminology

Digestion in ruminants differs from that in non-ruminants. The most important difference is the process of fermentation that happens in the rumen of a ruminant. We will need new terminology to describe the following processes:

- Rumination (also called chewing the cud): Coarse food stored in the rumen is brought back to the mouth cavity. It is then chewed into finer particles.
- Regurgitation: Swallowed food is brought back up into the mouth and expelled. Do not confuse this with rumination, where the food returned to the mouth is not expelled.
- Peristalsis: Food is moved down the alimentary canal by the alternating contracting and relaxing of circular muscles.

Intake of food – chewing the cud

Ruminants feed on various types of plant fibre. Fibres vary from lignin to hemi-cellulose to cellulose. The amount of plant fibre in the feed is known as roughage. The roughages are taken in by the animal, chewed and then swallowed. These roughages are then brought back to be re-chewed. This process is called chewing the cud. Young ruminants cannot do this as they do not have a properly developed rumen. The rumen develops when the calves are about six months old and they have to be weaned from cow's milk onto roughages. In young calves, the rumen is by-passed by the tubular groove or fold.

Cattle only partially chew their food. Large amounts of fibrous feed are swallowed and stored inside the rumen. This food can be taken back into the mouth cavity where it can be chewed into finer particles. Cattle chew for about one minute and then re-swallow the cud. This process enables the cow to take on large quantities of food very quickly and process it at a later stage. Ruminating has two main functions. It refines the food to make it more digestible to the microbes in the rumen. It also stimulates the flow of saliva to the rumen. The amount of time an animal spends chewing the cud varies per day. It depends on how much rough food the animal has eaten. It is therefore a good indication of the quality of the veld that the animal grazes on. Good quality veld contains a greater number of nutritious grasses with lower fibre content. Cattle grazing on good quality veld will spend less time chewing the cud.

Ruminating is stimulated by the presence of food in the rumen. Ruminating is made possible by a vacuum that forms in the upper part of the gullet. This vacuum is caused by the stretching of the chest cavity. The semi-liquid content of the rumen is then brought up into the mouth cavity by a strong contraction of the reticulum. When the cud arrives in the mouth, the cattle squeeze the liquid from it. Cattle then chew the cud into finer particles and swallows it again. Ruminating can be done several times until the food is sufficiently refined. The food is refined enough when it is able to move through the reticulum. Once the food is refined further it is swallowed and moves directly into the omasum.

Differences between a mature ruminant and a young ruminant

A newborn calf has, in effect, a single stomach. Only its abomasum functions and it therefore cannot ruminate. As the calf's forestomachs, the reticulum and rumen, develop, a microbial population also develops. This population consists of a mixture of bacteria and protozoa. The calf acquires these microbes through contact with older animals in the herd. When the calf starts to nibble on grass, the fermenting process can begin. Among the first micro-organisms to populate the calf's stomach are the *Lactobacillus* species. These bacteria digest milk sugar (lactose). They are slowly replaced by fermentation bacteria as the calf starts to eat solids (i.e. grasses and fodder) and the rumen starts to develop. It is important that calves are switched from milk to solid food to avoid stomach infections. Stomach infections can occur if the correct roughages for the action of the rumen bacteria are not available. This can cause an excess of *Lactobacillus*.

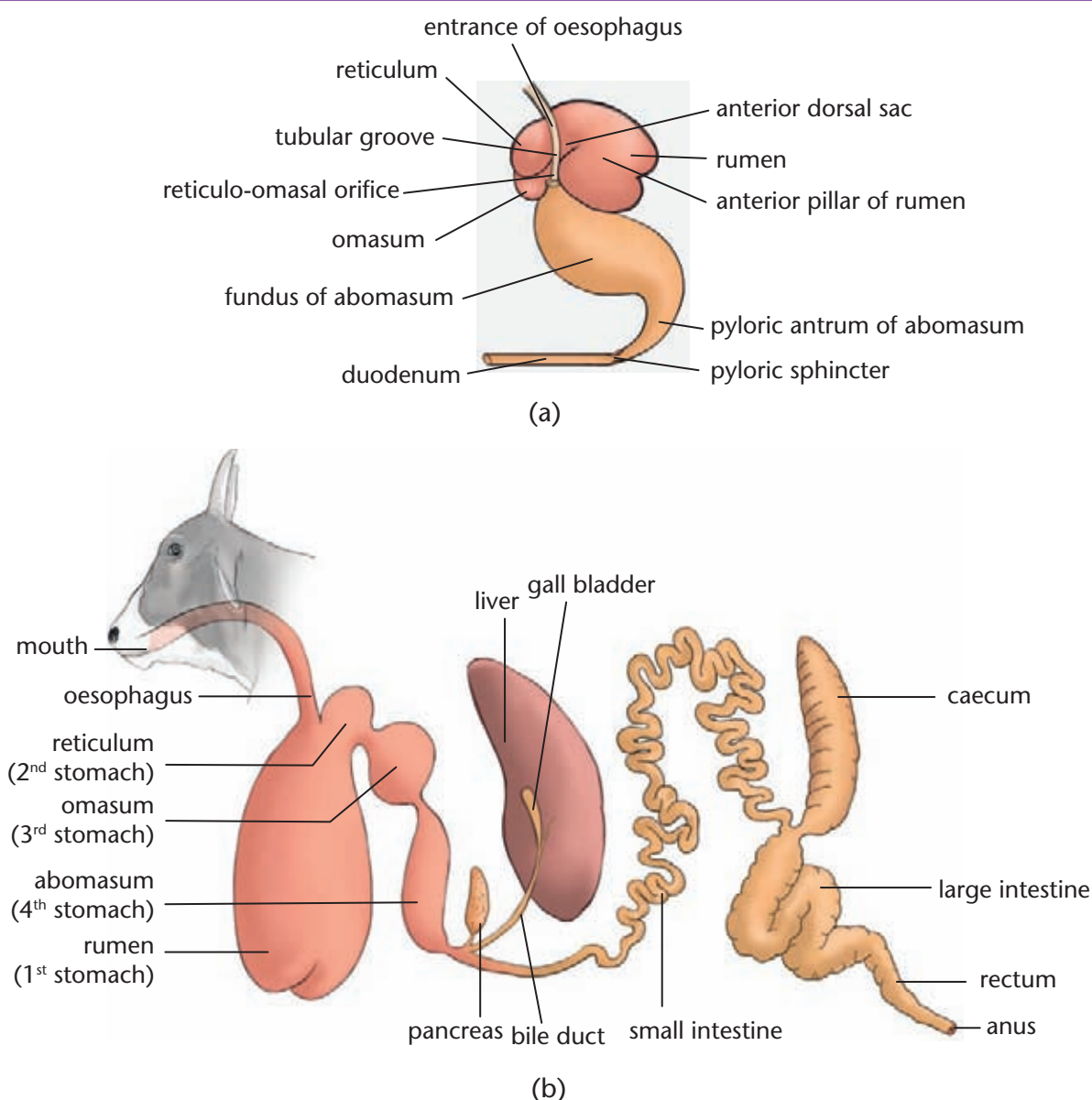


Figure 1.8: The forestomachs, stomach and duodenum of a newborn calf compared with an adult cow
(a) A newborn calf (b) An adult cow

Digestion in the rumen

The rumen plays a critical role in the ruminant's digestive process. You will learn that breaking down coarse food and passing it through the rumen, where micro-organisms turn the food into digestible matter, is an essential part of digestion in ruminants.

The concept of rumen microbes

Digestion in the rumen is a process of fermentation. Fermentation is carried out by microbes or microscopic organisms in the rumen. Rumen bacteria are living organisms. They play a very important role in the

digestive process of a ruminant. They live in **symbiosis** with the ruminant and enable it to digest cellulose. Symbiosis means that two living organisms live together and benefit each other.

Different types of rumen microbes

There are billions of micro-organisms living in an adult ruminant. They are mainly bacteria and protozoa. The bacteria are smaller and more numerous than the protozoa. The type of microbes present in a ruminant varies according to the ration on which it is fed. For example, the bacteria responsible for decomposing lignin differ from the bacteria that decompose green grass and **silage**. Animals do not gain mass when there is a change of feed, such as when they are moved from a winter feed of hay to early summer grazing, because the wrong bacteria are present in the rumen. However, over time the right type of bacteria multiply as the conditions become favourable for them. The animal can be 'inoculated' with the right type of bacteria to speed up the adjustment process. One can use the fresh stomach contents of the animal to find out what the right bacteria is. The right kind of bacteria can then be injected into the animal's bloodstream (inoculation), or more commonly, into the mouth, and they will find their way to the rumen.

Requirements for normal functioning of rumen microbes/micro-organisms

- Conditions in the reticulum and rumen must be favourable for micro-organisms so that they can function optimally. In this way, they can perform their important functions to the advantage of the ruminant.
- Micro-organisms require macro- and micro-elements for growth and reproduction. These elements are the same as those required by the animal itself, and they are obtained from the food that the animal takes in. Digestive enzymes break the food down and make these nutrients available to both the ruminant and the micro-organisms.
- The micro-organisms require a certain quantity of easily digestible carbohydrates, such as starch and sugars. The bacteria use these carbohydrates for energy, growth and reproduction. Therefore, dry feed can be supplemented with molasses to provide for the energy requirements of the bacteria. This is especially important during dry spells.
- Nitrogen strongly influences the micro-organisms living in the ruminant. It is used in the synthesis of microbe-proteins. Nitrogen is mainly derived from ammonia compounds. A ruminant's ration should therefore be supplemented with urea during the winter months. As micro-organisms die off, they are digested and, in turn, provide amino acids for the animal.
- Ammonia in the rumen must be above a certain critical level for most of the day to ensure a high rate of microbial growth and digestion and therefore feed intake. The level of ammonia that supports the best concentration of micro-organisms in the rumen (and therefore best digestion) will vary between diets.
- In order for rumen microbes to be numerous and active they must be well nourished. These microbes get their energy and nutrition from the feed source. A small amount of readily digested energy (e.g. molasses) can stimulate microbes when they are sluggish.
- About three-quarters (75%) of bacteria require nitrogen, sulphur and phosphorus to synthesize amino acids and protein. Protein in feed has to be broken down to these elements before bacteria can use them. Instead, these requirements can be supplied as urea, sulphur and phosphorus in a supplement.



There is a ratio at which absorption by the microbe is most efficient, so each element should be given in the correct ratio.

- The other quarter of bacteria (25%) require amino acids and peptides which are already formed. These bacteria can survive only when protein is available. In addition, minerals are required by microbes to build cell structure and to produce enzymes and vitamins.
- Dry roughage contains cellulose and hemi-cellulose that is bonded by lignin. This makes it less soluble and less digestible. Fungi and bacteria have to penetrate and break the plant structure to get access to the nutrients. The bacteria that ferment roughage survive in an environment where the pH is about 6.8 (range 6.2–7.2). The pH is dependent on the rate of production of saliva.
- Any nutrient, (including proteins, vitamins and minerals) that is deficient in a diet will result in low microbial activity in the rumen.

The types and numbers of rumen microbes are determined by the types of feedstuff fed to the ruminant. Some types of microbes require cellulose-rich feeds. Other types of microbes require starch-rich feeds. The implication of these micro requirements is that a livestock farmer should be very careful when switching from one kind of ration to another when feeding livestock – the microbe population has to adapt to the new rumen content.

Functions of rumen microbes

As mentioned earlier, the microbes living in the rumen of a ruminant play a crucial role for life on earth. They allow for crude fibre to be converted into soluble carbohydrates, which can be used by non-ruminants, such as humans, that eat the ruminants. The following functions are carried out by rumen microbes during the process of food digestion: they ferment plant material and synthesise amino acids and vitamins.

Absorption of food in the rumen by osmosis and diffusion into the bloodstream

End products of digestion are substances that have been simplified and made soluble or absorbable through the process of digestion. They are absorbed through the blood vessels and lymphatic system for distribution to the body tissues. The following table shows nutrients and their corresponding end products after digestion:

Table 1: Nutrients and their corresponding end products after digestion

Nutrient	End products
Protein	amino acids
Carbohydrate	glucose
Cellulose	fatty acids and salts of organic acids
Fats	fatty acids and glycerol
Minerals	in various soluble forms
Vitamins	in various soluble forms

The products of digestion can be absorbed by **diffusion** or via an active transport mechanism. An active transport system involves 'carrier' molecules in the cell membrane. These carriers attach to other molecules, such as fats, and transport them across the membrane and into the cell. This process uses energy, which is why it is called an active system. Diffusion and **osmosis** are passive processes that do not use the body's energy.

The fatty acids, ammonia and carbon dioxide are absorbed by diffusion through the walls of the blood vessels in the alimentary canal. Water and mineral salts such as sodium, calcium and magnesium are also absorbed straight from the rumen through diffusion.

Nutrients are absorbed in the smaller intestine of both ruminants and non-ruminants in exactly the same way. Folds in the cell wall of the small intestine increase the surface area used for absorption. The surface area is also increased by small finger-like extensions called villi. Villi are especially common in the duodenal part of the small intestine.

Water, minerals, amino acids, glucose and mineral salts are absorbed through diffusion and osmosis into the capillary blood vessels of the villi. These tiny capillary vessels eventually join together to form a larger blood vessel called a vein. The veins transport the end products to the liver.

Fatty acids and glycerol are absorbed into the lymph via the capillary lymph vessels. These vessels are found in the villi. The lymph joins the blood vessel system (the portal vein). Fats can be absorbed as chemically unchanged molecules. This is done by means of an active transport system. The colon absorbs mainly water, as well as certain fatty acids that are produced by rumen microbes.

Classroom activity 2

Work with a partner.

Answer the following questions. Keywords are given in brackets at the end of some of the questions. Use these keywords and give a reason or reasons for the following feeding results:

- 1 Pigs grow faster when their feed is finely ground. (single stomach)
- 2 Cattle (ruminants) will not prosper if their grazing is only soft and green. (volume)
- 3 When cattle are fed on only dry roughages, a sickness due to nitrogen deficiency will develop after time. (nitrogen)
- 4 Chickens will grow faster when their food is finely ground. (crop function)
- 5 If pigs are given food that is finely ground and boiled, they will grow faster. (enzyme)
- 6 When cattle graze on dry (winter) veld, it is necessary to give them a lick rich in sugar and urea. Explain why this is so. (microbe function)
- 7 Pigs can be fed on kitchen garbage. (enzyme function in single stomach)
- 8 Fowls can be fed on soft plant material such as green roughage, but not on dry roughage.
- 9 Cattle and sheep can survive a prolonged drought better than pigs and horses. (microbe activity)



- 10 Urea, instead of plant protein, can be fed to ruminants. (microbes)
- 11 Explain bloating in cattle. (rumen)
- 12 Ruminants can withstand a diet lacking in certain vitamins. (microbes)

Homework activity 2

Work alone.

Study the table below and then complete the last column. The first one has been done as an example.

The glands or the organ responsible for digestion	Enzymes secreted	Function/changes that take place
Mouth	Amylase	Changes polysaccharides to maltose
Stomach (non-ruminant) or abomasum (ruminant)	Rennin	
Gastric-juice glands	Hydrochloric acid	
Small intestine (liver), pancreas	Tripsin	
Pancreas	Amylase	
Pancreas	Lipase	
Succus entericus	Erepsin	
Succus entericus	Lipase	
Large intestine (colon)	No enzymes are secreted	

Extra practice 2

Work with a partner.

Complete the following table about the digestion of food in the alimentary canal of ruminants. This will help you prepare for your Grade 12 examinations.

Where digestion takes place	Glands	Secretions/enzymes	Most important functions
Mouth	Salivary glands	Saliva a) Ptyalin b) _____	Polysaccharides to maltose Maltose (disaccharide) _____ (monosaccharide)
	Mucous glands	Mucus	_____ the mouth and serves as a solvent for food
Stomach or abomasum	Gastric-juice glands	a) Rennin	Changes soluble _____ of milk to insoluble casein
		b) _____	Changes casein and proteins to peptides and polypeptides
		c) Lipase	Changes fats to fatty acids and glycerol
		d) Hydrochloric acid (not an enzyme)	Changes _____ to glucose and fructose Neutralises alkaline medium of saliva and acidifies it Activates the enzyme _____
Small intestine	Liver	Bile	Lubricates the alimentary canal Activates lipase Decomposes fats into smaller molecules
	Glands of Lieberkühn	a) Trypsin	Changes proteins and peptones to peptides
		b) _____	Changes _____ to maltose, dextrose and glucose
		c) Lipase	Changes fats to _____ and glycerol
		d) Succus entericus	Changes _____ to trypsin
		e) Erepsin	Changes peptides to _____
		f) _____	Changes sucrose to glucose and fructose
		g) Maltase	Changes _____ to glucose
		h) Lactase	Changes lactose to glucose and _____
		i) _____	Changes fats to fatty acids and glycerol



Unit 3: Components of feed

What you will learn about in this unit

- the functions (importance) of each of the following:
 - water
 - proteins
 - carbohydrates (sugar, starch and crude fibre)
 - fats and oils (ether extract) in animal production and growth
- the biochemical functions (importance and deficiencies) of the following mineral constituents:
 - macro-elements: calcium, phosphorus, magnesium, sodium, chlorine, potassium, sulphur
 - trace elements: iron, iodine, zinc, selenium, copper, cobalt
- the functions and two deficiencies of the following vitamins:
 - water-soluble: Vitamin B1, B2, B6 and B12 (Vitamin B complex)
 - fat-soluble: Vitamin A, D, E and K

Let's talk about this unit

The digestive system of any animal will be of little use if the animal does not have enough food to consume. Animal feeds or rations must be in sufficient quantities and qualities for the animal to grow and reproduce successfully. An appropriate ration is referred to as a balanced ration. A dairy cow will produce economically viable amounts of milk per day only if it has a balanced ration. The same is true for all livestock. In the next few units, we are going to examine the components of feed. We will examine their functions and importance, and what happens when an animal's diet is deficient in one or more of these nutrients.

What do I know already?



On early sea voyages, sailors suffered from a disease called scurvy. It was known that this was caused by a lack of fresh vegetables, but it was only in the early 20th century that it was discovered that the vital ingredient that could prevent scurvy was vitamin C. Today, pharmaceutical companies advertise cold remedies containing vitamin C every winter. Many other vitamins are offered for sale, including 'multivitamins'.



Why are fresh fruit and vegetables such an essential part of our daily diet? How do ruminants obtain their vitamins and minerals, as well as their other nutrients?

Word bank



biochemical reactions:	chemical reactions that take place in the living plant or animal
deaminated:	the removal of the amino group from an amino acid
ester:	an organic compound formed when an acid and an alcohol combine and release water
intermediate products:	products that are formed as part of the process of creating the end products of digestion
metabolism:	all the reactions that take place in a plant or animal
turgor:	the rigidity of a cell due to high water content
weaners:	young animals that have just stopped nursing, or suckling from their mothers



Figure 1.9: An example of a weaner

What I still need to know



The functions of water, proteins, carbohydrates, fats and oils in animal production and growth

Functions (importance) of water

A third to two thirds of an animal's mass consists of water. That water content of an animal varies with age. Newborns contain about 75 to 80% water, while an adult contains about 50% water. The loss of water can be fatal. An animal can go a few days without water, but as little as a 10% loss of water can cause death. It is obvious then that an animal needs access to an adequate supply of drinking water. The available water supply for livestock is determined by factors such as climate, the type of production and the moisture content of the food.

Functions of water in the animal's metabolism

- Nutrients and other substances are dissolved in water and are transported through the body in solution.
- Water is the medium in which **biochemical reactions** take place.
- The evaporation of water from the skin and lungs of the animal plays an important role in regulating body temperature.
- Water is the medium in which waste products are excreted, for example, as urine.
- Water creates **turgor** in the body's cells, which gives them strength and shape.
- Water protects the nervous system with a water cushion.



Figure 1.10: The importance of water



Functions (importance) of proteins

Proteins are very large molecules with a high molecular mass. Proteins vary in their solubility from very soluble to completely insoluble. Proteins change their nature through heating. A good example of this is cooking an egg. The proteins go from clear to white when they are heated. Protein molecules contain carbon, hydrogen, oxygen and nitrogen. Some proteins contain traces of sulphur, phosphorus or iron. Nitrogen makes up about 16% of many proteins and so the nitrogen content of food can be used to calculate the protein content of the feed.

Protein is important in an animal's diet as it is the main constituent of muscle. As mentioned earlier, before an animal can utilise protein it must be digested. The digestive process breaks down protein into amino acids. The animal's body then selects specific amino acids to build up into proteins again. These proteins are different from the plant proteins that were originally digested. Therefore, the new proteins can show absolutely no similarity to the proteins from which they came. For example, wool is made up of keratin. Keratin is a protein that is not found in plants, but is manufactured in the animal's body from amino acids originally obtained from grass and other vegetable matter.

Functions of proteins in animal metabolism

- Proteins provide amino acids for the animal. Amino acids are used as building blocks for new tissues and for repairing worn tissues. Younger animals therefore require more protein than adults, as the younger animals make more new tissues.
- Proteins are required for the production of hormones, enzymes and other secretions in the body.
- An excess of protein is **deaminated** and converted to fat, after which it is stored in the body as a source of energy.
- Some proteins form supportive tissue in the body, such as collagen, an important protein in the formation of ligaments, tendons and skin.
- Proteins are required for the production of products such as wool, eggs and milk.

Functions (importance) of carbohydrates

Carbohydrates are organic compounds that consist of the elements carbon, hydrogen and oxygen. More than 75% of the dry plant material used in animal feeding consists of carbohydrates. Carbohydrates occur in the body as an animal starch called glycogen. Glycogen is stored in the liver and the muscles. If the sugar levels in the blood become too low, the hormone insulin converts glycogen into glucose. This blood glucose is carried to all cells in the body where it provides energy for cell functions. Carbohydrates can be divided into different categories: monosaccharides and polysaccharides.

Monosaccharides (simple sugars)

Monosaccharides are the simplest of sugars; they cannot be sub-divided into simpler compounds. They are sweet and soluble in water. The most important monosaccharides found in plants are glucose and fructose.

Polysaccharides (complex sugars)

Polysaccharides are built up out of monosaccharides. Polysaccharides are very large molecules that are made up of hundreds of smaller monosaccharide molecules. Polysaccharides are insoluble in water. During digestion, polysaccharides are changed into **intermediate products** and then are broken down further into monosaccharides that are soluble and can be absorbed into the bloodstream. The important polysaccharides for animal nutrition are starch, glycogen and cellulose.

Starch

Starch is easily digestible and during hydrolysis it is changed into dextrin and then into the disaccharide maltose. Maltose is hydrolysed into glucose by the enzyme maltase. The digestion of starch in non-ruminants starts when the food is mixed with saliva in the mouth. The saliva of ruminants does not contain the enzyme amylase, and the starch is digested in the rumen by the rumen bacteria.

An important fact for the farmer to remember is that if the concentration of sugar in the rumen becomes high, bacteria in the rumen will exist mainly on that sugar. They will not digest the cud, and will therefore not release the nutrients in the cud (grass or feed). This will lead to a loss of nutrients for the animal.

Glycogen (animal starch)

Carbohydrates are stored in the animal's body in the form of glycogen. Glycogen is made up of glucose molecules. Glycogen is found in most animal cells and is stored in the muscles. Glycogen can be changed into glucose and plays a vital role in the energy **metabolism** of the animal.

Cellulose (crude fibre)

Cellulose is mainly found in plant material. It is made up of glucose molecules that are bound together by strong bonds. This makes cellulose hard to digest. Non-ruminants cannot digest cellulose. Certain rumen bacteria are able to change cellulose to glucose, which makes it possible for cellulose to be used as a primary source of energy for ruminants.

Functions of carbohydrates in the animal's body

- Carbohydrates are the most important source of energy for the animal.
- Carbohydrates play an important role during the fattening of farm animals. The fat in an animal is built up from excessive carbohydrates in the ration.
- Crude fibre plays an important role in the bulkiness of a ration, which improves the functioning of the alimentary canal.

Functions (importance) of fats and oils (lipids)

'Lipid' is a collective name for fats, oils, waxes and similar compounds such as phospholipids, which act as emulsifiers for fats. Lipids are organic compounds that are comprised of carbon, hydrogen and oxygen. They are insoluble in water, but are soluble in ether, chloroform and benzene. Fats and oils are **esters** of the alcohol glycerol and are composed of one molecule of glycerol and three fatty acid molecules. The fatty acid molecule may:

- possess a double bond between adjacent C atoms (unsaturated, for example, oleic acid)
- possess no double bonds between adjacent C atoms (saturated, for example, stearic and palmitic acids).

'True' fats that are comprised of mainly unsaturated fatty acids tend to be liquid at room temperature. They are called oils. Saturated fatty acids tend to be solid at room temperature and take the form of butter, cheese and other dairy products.

Lipids are important in animal nutrition. Stearic, palmitic and oleic acid are all very important fatty acids in animals. The function of fatty acids and lipids in the body is discussed below.

Ordinary roughages, such as grazing, contain very little fat. As such, the most important sources of fats are from oils such as linseed or cottonseed. Feed concentrates contain up to 10% fats and oils. Feeds that are of animal origin, such as meat, contain a large proportion of unsaturated fat. Bone meal can contain up to 12% fat.



Fats are a good source of energy because they release as much as 2,25 times more energy than carbohydrates. This is because of the high carbon and hydrogen contents of fats.

The animal can synthesise fats from carbohydrates. A greater percentage of body fat is derived from carbohydrates in the animal’s ration.

During digestion, fats and oils are digested in the alimentary canal into glycerol and fatty acids. These are absorbed in the body and transported by the bloodstream to the muscle and fatty tissues where they recombine to form fat. Fat is a storage place for energy. If an excess of unsaturated fat is included in the ration, it may have a detrimental effect on the body fat – mainly soft, oily meat is formed. This can lower the quality of the carcass. Feeds such as maize meal and oil-cake meal can have this affect if they are fed in excessive quantities.

Functions of lipids in the animal body

- Lipids are involved in the building up of cell membranes. They form water repellent (or hydrophobic) layers of the cell membrane. These layers helps to control which substances move in and out of the cell.
- They serve as a concentrated source of energy. Large quantities are stored for later use in the muscles.
- The fatty layer under the skin serves as an effective insulation against heat exchange.
- Fat protects internal organs such as the kidneys, by forming a protective layer.

The biochemical functions of macro-elements and trace elements

Biochemical functions (importance and deficiencies) of macro-elements

There is a distinction between organic and inorganic substances in animal feeds. In this section, we will focus on inorganic substances. Inorganic substances that have a nutritional value are called minerals. We can subdivide minerals into macro- and micro-elements. We make this distinction on the basis of the quantity required by the animal’s metabolism. Micro-elements are also called trace elements.

The next table lists the elements, along with their corresponding symbols, that are essential for an animal’s metabolism.

Table 2: Macro-elements and micro-elements

Macro-elements	Symbol	Micro-elements	Symbol
Calcium	Ca	Iron	Fe
Phosphorus	P	Iodine	I
Magnesium	Mg	Zinc	Zn
Sodium	Na	Selenium	Se
Chlorine	Cl	Copper	Cu
Potassium	K	Cobalt	Co
Sulphur	S		

Functions (importance) of macro-elements

Calcium

Calcium is essential for the formation of the skeleton and the teeth. Calcium plays a role in the sensitivity of nerve tissues.

Phosphorus

Together with calcium, phosphorus is essential for the formation of the skeleton and teeth. It also makes up nucleic acids and phospholipids.

Magnesium

Magnesium forms part of the bone structure. It is the activator for a number of enzyme systems. Magnesium is the most common cation in the blood and plays a role in the buffer systems of the body.



Figure 1.11: Calcium is essential for the formation of healthy teeth.

Sodium

Sodium plays a key role in the nutrient exchange mechanism. This mechanism distributes nutrients among the cells in the body. Sodium is essential for conducting the impulses in the nervous system. Sodium is also an important part of saliva, and plays a role in the acid-base equilibrium of the body. It plays an important role in the osmotic regulation of body liquids.

Chlorine

Chlorine forms the main anions in the body's liquids outside of the tissue cells of the animal.

Potassium

Potassium is involved in the acid-base equilibrium of the body. Potassium helps regulate osmotic pressure in the body.

Sulphur

Sulphur makes up part of some amino acids such as cysteine and methionine. It also forms part of some vitamins such as biotin. Sulphur is required for the formation of wool fibres and is required by rumen microbes for synthesising sulphur-containing amino acids.

Deficiencies of macro-elements

Calcium and phosphorus

A calcium shortage causes milk fever in lactating cows. A calcium and phosphorus deficiency in the diet will result in bone diseases such as rickets, stiff-sickness and osteomalacia. Generally, osteomalacia presents symptoms in animals just after they have been weaned. The following is a list of common symptoms:

- Animals show a salt hunger by chewing bones, wood, etc. This phenomenon is called pica.
- The legs are bent and cannot support the body mass.
- There is a thickening of the knee and hock joints.
- Animals exhibit stiffness in general.
- The spinal column becomes compressed.



Magnesium

A magnesium deficiency results in a disease known as hypomagnesaemia. The symptoms of this disease are:

- The animal is nervous and has pricked-up ears and staring eyes.
- It walks stiffly and staggers.
- Dairy cows show a decrease in milk production.
- The animal becomes hypersensitive, goes into a coma and dies.

Sodium

A sodium deficiency results in a reduced rate of growth, fertility, reproduction and milk production. The animal also shows a decrease in food intake and feed efficiency. A salt (NaCl) deficiency can lower the quality of the carcass.

Chlorine

A lack of chlorine in the diet can slow the cellulose digestion in the rumen of ruminants.

Potassium

A variation in the potassium levels in the diet causes the cellulose digestion in the rumen to differ.

Sulphur

A sulphur deficiency is very rare. When it does occur, certain amino acids (such as cysteine) cannot be synthesised. This can cause wool fibre to break, as cysteine is a building block of this fibre.

Biochemical functions (importance and deficiencies) of trace elements (micro-elements)

Although trace elements are only required in small quantities, any deficiency can lead to major metabolic disorders. Trace element deficiencies occur in areas such as sour veld, where the minerals have been washed out of the soil.

Functions (importance) of trace elements

Iron

- Iron is an essential part of haemoglobin in red blood corpuscles, in which oxygen is carried from the lungs to the cells.
- It forms part of the protein that occurs in the spleen, liver, kidneys and bone marrow.
- Iron is also part of various enzymes in the animal's body.

Iodine

- Iodine is a constituent of the hormone thyroxine, which is secreted by the thyroid gland.
- Thyroxine plays an important role in regulating the body's metabolic rate.

Zinc

- Rumen organisms require zinc to carry out their metabolic reactions to completion.

Selenium

- Selenium helps with the absorption of vitamin E.
- It prevents the degeneration of the pancreas.

Copper

- Copper plays a role in the formation of blood.
- It plays a role in the enzyme system that maintains the nervous system.
- It is involved in pigment formation of wool and hair. It is also responsible for the normal waviness of Merino wool.
- It ensures the normal calcification of the bones in the skeleton of an animal.
- Copper is required to maintain fertility.

Cobalt

- Cobalt is a building block of vitamin B12. Vitamin B12 is produced by bacteria in the rumen and is needed for normal growth and the synthesis of haemoglobin.
- Because cobalt is part of the food component of rumen bacteria, it is required for the fermentation of roughages.

Deficiencies of trace elements

Iron

An iron deficiency causes a disease known as anaemia. The symptoms of this disease are:

- The mucous membranes in the mouth, eyelids and vulva are pale.
- The animal appears listless and tired.
- It has an accelerated heartbeat and rapid breathing.
- It has a depressed appetite, which is followed by diarrhoea and a salt hunger.
- Piglets develop wrinkled skin and a swelling of the head and shoulders.

Iodine

A lack of iodine depresses thyroxin production, which causes the thyroid glands in the throat to enlarge. This enlargement is known as goitre. Goitre is characterised by the following symptoms:

- hairless, weak or dead young
- premature ageing and listlessness in adult animals.

Zinc

A lack of zinc causes:

- reduced growth speed in pigs
- food utilisation to become inefficient
- skin disturbances to occur, for example:
 - the skin of the stomach becomes bright red
 - a skin rash occurs, which develops into a hard mange of the skin
 - raw sores occur and the wounds heal very slowly.

Selenium

A selenium deficiency results in:

- muscular dystrophy
- the occurrence of heart diseases
- a slower growth rate
- a lowered fertility rate



- general lameness
- the same symptoms as a vitamin E deficiency (you will learn more about these in the next section).

Copper

The most important deficiency disease resulting from a copper deficiency is swayback. Swayback occurs mainly among young animals and is characterised by the following symptoms:

- The hindquarters become paralysed. This is where the name swayback comes from. This symptom of paralysed hindquarters can vary from a lack of coordination to the complete inability to stand.
- The disease is incurable and so has a high mortality rate.
- Copper deficiency also causes an absence of pigment or a reddish discolouration of black hair or wool.

Cobalt

A deficiency in cobalt will result in a disease known as wasting disease. The symptoms are as follows:

- appetite loss, which will lead to a loss of mass and, eventually, anaemia and death
- an excessive secretion of mucus from nose and ears
- a drop in milk and wool production
- fertility is negatively affected.

The functions and deficiencies of vitamins

Animals that are kept on natural grazing usually receive all their vitamins from the veld. As soon as animals are kept under intensive conditions of production, vitamin deficiencies can occur. In other words, if the supply of nutrients does not match the rate of production, deficiencies result. Animals in areas stricken with drought also can experience vitamin deficiencies.

Vitamins are organic compounds that are required in small quantities for normal metabolism in animals. Vitamins are catalysts. This means that vitamins speed up biochemical reactions in the animal's body while they, themselves, remain unchanged.

Vitamins can be soluble either in fat (such as vitamins A, D, K and E) or in water (such as the B-complex vitamins and vitamin C). Water-soluble vitamins cannot be stored in the body and must be taken in daily. The following table lists the main vitamins. The first column shows their predominant functions and the second the symptoms of deficiency.

Table 3: Water-soluble and fat-soluble vitamins

Function of the vitamin	Deficiency symptoms of the vitamin
Water-soluble vitamins	
Vitamin B1 • serves as a co-enzyme in carbohydrate metabolism	• loss of appetite, which results in loss of mass • weakening of the nerve cells • female animals will not come into heat • birth rate is lower and mortality rate higher • lactation decreases in cows • hens hatch fewer eggs

Function of the vitamin	Deficiency symptoms of the vitamin
Water-soluble vitamins	
Vitamin B2 is a prerequisite for normal growth	- loss of appetite, which results in slow growth - skin rashes and eye abnormalities - a disease known as curled-toe paralysis occurs in chickens - pigs experience symptoms such as chronic diarrhoea, skin sores, stiff limbs and sore eyes
Vitamin B6 - is a constituent of co-enzyme A - plays a role in biochemical reactions such as fat and cholesterol synthesis - is involved in cell respiration	- leads to growth and reproduction failures - skin and hair lesions - a retardation of growth and feather development in chickens - scurvy skin and thin hair in pigs - pigs exhibit a characteristic goose-stepping
Vitamin B12 - plays a role in various metabolic reactions - is essential for cell division	- growth is retarded - hens experience poor egg hatching - pigs experience pain in the hindquarters, which results in an unsteady walk
Fat-soluble vitamins	
Vitamin A - plays a role in the sharpness of normal vision - controls bone growth - required for a healthy mucous membrane in the body - required for fertility in both male and female animals	- poor night vision; eventually it can lead to blindness - gives rise to deformed, weak or dead young - fertility is reduced and can lead to total infertility
Vitamin D - helps with the absorption of calcium and phosphorus - plays a role in depositing calcium and phosphorus in growing bone - plays a role in the synthesis and functioning of hormones	- a decrease in food consumption, which results in slow growth - rickets in young animals; rickets is a disease where the bones of the animal are weak and break easily - adult animals experience brittle bones, known as osteomalacia
Vitamin E - counteracts the oxidation of unsaturated fatty acids - plays a role in normal cell respiration	- the degeneration of embryos in fowls - muscle degeneration in sheep - liver degeneration in pigs
Vitamin K plays a role in blood clotting	bleeding, which cannot be stopped, and which will lead to the death; common in chickens



Classroom activity 3

Work alone.

Complete the following sentences by filling in the missing words:

- 1 The main component of feed is water. The remainder is known as dry material, which consists of the following nutrients:
 - a) _____
 - b) carbohydrates
 - c) _____
 - d) minerals
 - e) _____
- 2 The main functions of nutrients in the animal body are:
 - a) to provide _____ and energy
 - b) to replace worn _____
 - c) to promote _____
 - d) for _____ and production.
- 3 Two-thirds of the mass of an animal's body consists of water. Water is particularly important as a _____, lubricant, _____ agent and cooling medium in the body.
- 4 Proteins consist of the elements carbon, hydrogen, oxygen and _____.
- 5 Proteins are made up of amino acids. They are important for _____, production, reproduction and are a constituent of enzymes and _____.
- 6 Carbohydrates consist of the elements _____, hydrogen and oxygen and are particularly utilised by an animal for heat and energy, as well as the formation of _____.
- 7 Carbohydrates are subdivided into:
 - a) monosaccharides (simple _____).
 - b) _____ saccharides (_____, glycogen, cellulose).
- 8 Fats and oils are built up of the same elements as carbohydrates, but possess relatively more _____ atoms per molecule.
- 9 Fats and oils release two and a quarter times more _____ than carbohydrates during oxidation.
- 10 Unsaturated fatty acids possess _____, while saturated fatty acids possess no _____ between adjacent carbon atoms.
- 11 Vitamins can be subdivided into fat-soluble vitamins _____, _____, _____ and _____ and the water-soluble vitamins _____ and _____.
- 12 With a deficiency of vitamins, certain deficiency _____ may occur.
- 13 Ruminants synthesise _____ of the B complex.
- 14 Minerals are subdivided into _____ and _____ elements.
- 15 Mineral elements perform one or other _____ function in the animal cell.

Homework activity 3

Work with a partner.

Read the objectives listed below. Decide what kind of feed you would include in the animal's daily ration to achieve the objective. Give a reason for your decision in each case.

- 1 You want to put your weaner lambs through a fattening programme to fatten them for market.
- 2 You want to increase the milk production of your dairy cows.
- 3 It is the dry season and you want to make sure that your beef cattle herd does not lose weight.
- 4 You want your rams to be highly fertile during the mating period.
- 5 You want to increase your laying hens' production.
- 6 Your draught animals, such as horses, will be doing heavy farm work during the winter months. You want to make sure they are strong enough to do the work.
- 7 Your beef herd is in calf and the natural pastures are dry.
- 8 You are farming in a high-rainfall area and the soil is coarse. There are symptoms of mineral deficiency in your sheep's wool.
- 9 Your beef cattle herd is grazing on green pastures such as oats, and you want to sell weaners from these pastures.
- 10 You want to fatten a bullock for your own consumption.

Extra practice 3

Work with your group.

- 1 Read the three conditions listed below. For each condition, write down what kind or kinds of feed will form the main part of the livestock's daily ration.
 - a) High rainfall with dense vegetation during the whole year.
 - b) High rainfall with sour veld because of sandy soil.
 - c) Shrubs and thorny bush under arid conditions.
- 2 Some environmental conditions can cause nutrient deficiencies in livestock. Listed on the next page are some environmental conditions that could cause such deficiencies. Draw a table with two columns. Use your knowledge of different veld types (from Grade 10 Agricultural Sciences) to identify the kinds of deficiencies that could occur under each climatic condition, and write the answers in column 1. In column 2, write down the corresponding symptoms displayed by the animals. For example:

	Deficiency or deficiencies that occur under the climatic condition	Symptoms displayed by the animals
A.		
B.		



	Deficiency or deficiencies that occur under the climatic condition	Symptoms displayed by the animals
C.		
D.		
E.		

- A severe drought leaves your sheep farm without green pastures.
- You are farming with beef cattle in a high-rainfall region with well-drained soils.
- You are managing a fat lamb production unit in a sandstone area.
- You are feeding your broiler unit solely on ground yellow maize.
- You are keeping your dairy herd on artificial green pastures such as kikuyu and supplementing their ration with dry lucerne fodder.

Unit 4: Digestibility of feeds – biological value, energy value and nutritive ratio

What you will learn about in this unit

- **digestibility of feeds**
 - the concepts: digestibility and digestibility coefficient of feeds
 - factors that affect/influence/determine digestibility of feeds
 - the methods of improving/increasing digestibility of feeds
 - calculation and interpretation of the digestibility coefficient of a feed
- **quality of feed: biological value of proteins**
 - the concepts: biological value (BV), essential amino acid index and ideal proteins
 - the importance of animal proteins in rations
 - evaluation of feed in terms of biological value, for example egg and milk
- **energy value of feed**
 - the units in which energy value (EV) is expressed
 - the terminology: gross energy, metabolic energy, digestible and nett energy
 - the purpose/aim of calculating the energy value of feed
 - schematic representation of feed energy flow
 - calculation of feed flow and interpretation of the results
- **nutritive ratio**
 - the concept: nutritive ratio (NR)
 - the purpose/aim of the nutritive ratio in animal feeding
 - calculation of the nutritive value of a feed and interpretation of the results

Let's talk about this unit

The growth of an animal and the production of products such as meat, wool or milk, depend largely on the ratio of feeds in the animal's daily ration. The energy value of feeds is important for the general health of the animal. There should be a balance between the content of the protein, vitamins and minerals of the feed, and its energy content (in the form of carbohydrates). An unbalanced ration leads to under-performance and reduced levels of production. In this unit, we will examine factors affecting the nutritional value of feeds. We will examine the biological value of proteins, the energy value of feeds and the nutritive ratio in animal feeding.

Some feeds have a greater potential nutritive value than others. This means that they are more nutritious. The **nutritive value** of a feed indicates how important it is to the daily ration of an animal.

Feeds are of no use if they cannot be absorbed into the bloodstream and transported to different parts of the body where they are needed. To be absorbed by the bloodstream and utilised by the body, it is necessary for the feed to be broken down into its smallest particles, i.e. it must be digested. Feeds differ in their digestibility. In this unit, we look at the ability of different feeds to be digested.

What do I know already?



You may have encountered the symptoms of poor digestion, for example feelings of bloating or heartburn from eating too much of the wrong kinds of food. Poor digestion, you should know, results in symptoms such as heartburn, headaches, nausea and diarrhoea.



What kind of food do you struggle to digest? Discuss with your partner why you think this is so. Can you classify these foods? Are they proteins or carbohydrates? Why do you think people have difficulty digesting high-fibre carbohydrates?

Word bank



nutritive value:	the value of a feed in providing nutrition to the animal
rectified:	correct a mistake
supplement (a ration):	to add a nutrient or mineral to a ration
warm-blooded animals:	warm-blooded animals are able to regulate their own body temperature through the blood (in contrast to cold-blooded animals)

What I still need to know



Digestibility of feeds

The concepts digestibility and the digestibility coefficient

Not everything that an animal eats is digested. Some parts of any feed will go through the alimentary canal and remain undigested. The livestock farmer must know what percentage of the feed is absorbed in the alimentary canal of the livestock animal. This percentage is called the digestibility coefficient and it gives the value of a feed.



Definition of digestibility and digestibility coefficient

Digestibility of feed is the portion of any feed that will be digested in the alimentary canal of an animal or human.

Digestibility coefficient is the portion of any feed which was taken up by an animal (and not excreted), expressed in terms of dry material as a percentage of the total feed.

Factors that affect/influence/determine the digestibility of feeds

The crude fibre content of a feed

The crude fibre content of a feed has the greatest single influence on its digestibility. The greater the percentage crude fibre, the less digestible the feed will be.

Quantity of feed taken in

The more feed taken in at a time by an animal, the faster the food moves through the alimentary canal – with a resultant lower digestibility of the feed.

Individuality

Animals differ with respect to their individual ability to digest feeds. Animals of the same breed, under the same conditions and fed the same rations, may digest feed differently.

Composition of the ration (associated effect)

The digestibility of a feed is also determined by the relationship in which it occurs with other feeds in the ration.

The age of the plant when it is cut down for hay

The crude fibre content of a natural pasture or fodder crop increases as the plants reach maturity. The plant, especially the stem, becomes woodier. The woodier the plant, the less digestible it is. Green, soft plants contain easily digestible carbohydrates and proteins. As the plant grows older and becomes dry and woody, these easily digestible compounds are turned into tough, woody substances such as cellulose and lignin.

The way in which the hay is prepared

If a large percentage of leaves are lost when the hay is gathered and baled, the feed will consist mainly of stems. The stems have a low digestibility. In practice, fodder crops should always be baled when the hay is damp, but not wet, and so it should be done in the early morning.

The texture of the hay

When hay is milled, its digestibility increases (provided it is not dusty). Milled hay that is converted into pellets has an even higher digestibility.

The alimentary canal of the animal

The percentage of crude fibre in the feed affects the digestibility of the feed. The greater the percentage of crude fibre in the feed, the less digestible the feed is. The same is true for ruminants and non-ruminants.

For ruminants, the digestibility of the feed is determined by the composition of the feed. Fodders with low protein content will be less digestible than protein-rich fodder. The quality of the carbohydrates in the feed also determines how digestible the feed is. Feeds with easily digestible carbohydrates, such as cellulose and hemi-cellulose, will be easily digestible for ruminants. Feeds with very fibrous plant material, such as lignin, will have a lower digestibility coefficient.

The methods of improving/increasing digestibility of feeds for ruminants

Grinding, crushing or chopping of feed

It is often assumed that by grinding or chopping feed, the value of the feed – its digestibility – is increased. However, this is not always true. Making feeds so fine that they can be swallowed without chewing, lowers the value of the feed.

The value of grinding, crushing or chopping feeds depends on the kind of feed and also on the kind of animal fed.

In the case of grain, grinding, crushing or soaking it is only profitable when the particular animal fails to chew the feeds thoroughly.

Pellets or cubes

Pellets are made in special machines. Pelletizing reduces the bulk and is used for outdoor feeding – because there is less wastage from wind and weather. Pelletizing increases the digestibility of roughages (hay) significantly.

Supplement crude fibre (plants/roughages) with urea and molasses

It is a common practice to **supplement** hay with urea and molasses. Supplementing is usually done during the dry seasons.

Urea is a non-protein nitrogen (NPN) molecule. It supplies the necessary nitrogen to the microbes in the rumen. As you discovered in Unit 2, microbes in the rumen of ruminants can use the nitrogen from urea to synthesise protein. As these microbes die off, they are digested and they, in turn, provide amino acids to the animals.

Protein is an expensive nutrient and it is often deficient in natural grazing and most roughage. NPN can replace at least one third of the natural protein in the ration. Rumen microbes are able to produce protein from nitrogen compounds such as urea. A carbohydrate-rich feed must be fed with the NPN to provide energy for the rumen microbes.

Methods of urea provision

- A mixture of 2 kg urea and 20 kg molasses is dissolved in 12 ℓ of water. This mixture is sprayed over natural grazing or low-grade roughage.
- Licks containing urea and molasses can be given to ruminants.
- Include concentrates of 1 to 2% urea to dairy cows, beef cattle and sheep.

Calculation of the digestibility coefficient of feed

When an animal takes in, for example, 100 kg of feed and 40 kg is excreted, one can assume that the animal's body has used 60 kg of that feed. This can be expressed as a percentage of the original mass of the feed. This is called the digestibility coefficient. Here is the formula for calculating the digestibility coefficient:

$$\begin{aligned}
 & \frac{\text{Feed-intake less manure excreted}}{\text{Feed intake}} \times \frac{100}{1} \\
 = & \text{Digestibility coefficient} \\
 & \frac{100 - 40}{100} \times \frac{100}{1} = 60\%
 \end{aligned}$$



When you calculate the digestibility coefficient of feed it is important to remember how much water the feed contains. In the case of moist or green roughages, such as silage or green lucerne hay, you must subtract the amount of water that it contains. This is because water is not regarded as a nutrient. For example, if the hay has a moisture content of 15%, the digestibility coefficient will be calculated as follows:

$$\begin{aligned} & \frac{(100 - 40) - 15}{100 - 15} \times \frac{100}{1} \\ &= \frac{45}{85} \times \frac{100}{1} \\ &= 53\% \end{aligned}$$

The moisture content of a feed can be determined by weighing a certain mass of fresh feed, drying it in the sun for three days and then weighing it again. The difference in weight will give you the difference in mass between the fresh and dry feed. This difference is the moisture content.

Here is an example of how the digestibility coefficient is determined by using the formula:

	Dry material	Crude protein	Crude fibre	Non-nitrogen extract	Ether extract
49,0 kg mealies	kg 42,33	kg 4,80	kg 0,94	kg 34,32	kg 1,70
12,6 kg manure	4,60	0,86	0,62	2,11	0,59
Quantity digested	37,73	3,94	0,32	32,21	1,11
Coefficient of digestibility	% $\frac{37,73}{42,33} \times \frac{100}{1}$ = 89,13	% $\frac{3,94}{4,8} \times \frac{100}{1}$ = 82,08	% $\frac{0,32}{0,94} \times \frac{100}{1}$ = 34,04	% $\frac{32,21}{34,32} \times \frac{100}{1}$ = 93,85	% $\frac{1,11}{1,70} \times \frac{100}{1}$ = 65,29

Interpretation of the digestibility coefficient of a feed

The livestock farmer will have no need to do the above experiments on the digestibility coefficient of feeds. He or she can obtain all the information on the digestibility of feeds (mealies in our example above) from lists of the average composition and the digestibility of feeds from different sources like: Frank B Morrison, *Feeds and Feeding* (abridged) pp. 538–604. The digestibility figures in Morrison are based on analyses done in the USA. Closer to home the farmer can find information on the digestibility of feeds – obtained from experiments done in South Africa – in publications such as *Beef in Natal* compiled by GA Jacobs, pp. 4–15. If the farmer wishes to use these (and other tables) of feed analysis it is necessary to have the correct background knowledge. This is because the values of these feed are not constant. Nonetheless these values can serve as guidelines to compile rations for your livestock.

The tables assist in deciding how much each feed (for example how much mealies, oats, silage, barley and other feedstuffs) should be supplied and in what ratio. Since mealies have a high digestibility coefficient of carbohydrates and a low digestibility coefficient of proteins, the farmer should add a protein-rich feed compensate for the low nitrogen content of mealies. Oats, for example, which have a high protein digestibility coefficient, would be a suitable supplement.

Quality of feed – biological value of proteins

Protein content is a significant indicator of the quality of a feed. However, protein is very expensive and does not always contain all the essential amino acids required for metabolism. Proteins that have a high quantity of essential amino acids are said to have a high biological value.

The concepts: biological value (BV), essential amino acid index and ideal proteins

We can define the biological value of protein as the percentage of the digested protein that is used for both maintenance and growth of a living organism. It is the most common laboratory method of measuring the nutritive value of the protein in a ration.

For a protein to have a high BV, it must have amino acids of high quality. Amino acids of high quality are those that cannot be synthesised by micro-organisms in the rumens of ruminants. These are referred to as essential amino acids. The amino acids that can be synthesised by micro-organisms in the rumen of ruminants are known as non-essential amino acids.

The essential amino acid index is a measure of the quality of a protein by comparing it with the quality of the protein in an egg. If a protein has a high index, then it is a high-quality protein containing many essential amino acids.

This protein can also be referred to as having a high biological value, or it can be called an ideal protein.

The importance of animal proteins in rations

- Animal proteins provide amino acids to the body for the repair of worn tissues and the building up of new tissues (growth). For this reason, a young, growing animal requires more protein than an adult animal.
- Proteins are required for the production of hormones, enzymes and other secretions in the body.
- An excess of protein is deaminated, after which it serves as a source of energy in the form of animal fats.
- Proteins serve as building blocks for the synthesis of supportive structures in the body.
- Proteins are required for the production of protein-rich products such as wool, eggs and milk, and are also required for reproduction.
- Proteins play a role in the regulation of metabolism.

Table 4: Common proteins and their BVs

Animal protein	BV
Milk protein	95%
Fishmeal	90%
Beef	76%

Plant protein	BV
Maize	60%
Wheat	67%
Soya beans	75%



Evaluation of feed protein in terms of their BVs

Since egg protein is used as the standard unit of measure for proteins, it is taken to have a BV of 100. When you compare different proteins with egg protein, you will find that animal proteins have a relatively higher BV than proteins of plant origin.

The following is a table that compares the BV and origin of some common protein sources.

Table 5: BV and the origin of common protein sources

Protein	Origin	BV
Maize	Plant	60
Wheat	Plant	67
Soya beans	Plant	75
Beef	Animal	76
Milk	Animal	95
Fish	Animal	90

Rectifying amino acid deficiencies

Amino acid deficiencies can be **rectified** by mixing different feeds. A feed should never contain only one type of protein. Instead, it should include different proteins with different biological values. A mixture of two or more low-quality proteins may supplement one another and result in a satisfactory BV. It could happen that a ration with a variety of proteins will have a higher BV than a ration consisting of only a few proteins. It is important to include animal proteins in the ration as they are high-quality proteins and supply various amino acids that are in short supply in plant proteins. Proteins of both plant and animal origin are mixed in the ration to be more cost effective, as plant proteins are generally cheaper than animal proteins.

Energy value of feed

When you plan a ration for your livestock venture, you need to consider the protein value of feeds as well as the energy value (EV) of the feed. The energy value of the feed is determined mainly by the quantity and quality of the carbohydrates in the ration. There are many different kinds of carbohydrates, for example sugars, starch, hemi-cellulose, cellulose and lignin. Sugars and starch have a higher energy value when compared with carbohydrates such as cellulose or lignin.

The units in which energy value is expressed

The energy value of a feed is measured by burning a sample in a laboratory (a process called controlled combustion). When a feed is burnt, the heat released per gram can be measured. This is referred to as the gross energy of a feed. Although carbohydrates are a good energy source, fats have a higher energy value. They require more energy to burn, but they also release more energy when they are broken down in the body by metabolic processes. Fats are therefore a valuable store of energy in the body. Carbohydrates release less energy, but are much easier for the body to metabolise. Hence the animal's body first breaks down the carbohydrates in the feed to provide energy, while the fats are stored to be used when carbohydrate levels drop.

The energy value of feed is measured in terms of kilojoules (kJ). Fats have 39 kJ of energy per gram and carbohydrates have 17 kJ of energy per gram. Unfortunately, the animal does not utilise all the feed that it consumes. Normal energy losses do take place through the faeces and urine, as well as through heat generated by the body's metabolism.

Terminology: gross energy, metabolic energy, digestible energy and nett energy

Gross energy

When a substance is burnt into its oxidation products, namely CO_2 and H_2O , the energy that is released as heat is called the gross energy. This energy value of feeds is determined in a laboratory. The following values are determined:

- Carbohydrates – 17,2 kJ per gram
- Fats – 39,6 kJ per gram
- Proteins – 23,7 kJ per gram

It is clear that fats have a higher energy value than the other nutrients. Feeds with a high fat content, for example oil-seeds, therefore have higher energy values than those low in fat content, for example the cereals.

Metabolic energy

Metabolic energy is the gross energy value of a feed minus the energy lost in the faeces, urine and end products of digestion. In ruminants, energy is also lost due to gases that are produced when carbohydrates are broken down by microbes. Methane is the primary gas produced in this way. These gases represent an energy loss for the animal. Energy is also lost during the metabolism of protein. The nitrogen-containing products of protein metabolism are excreted through the urine.

Digestible energy

Not all energy that is ingested is used. The digestible energy (DE) value is the difference between the gross energy value of the feed and the energy that is lost through the faeces. We can determine the DE of a feed by determining the combustion heat energy of manure then subtracting it from the gross energy of the feed.

Nett energy

Nett energy is the difference between the EV of a feed and the energy that is lost through faeces, digestion, etc. Energy can also be lost as heat. The chemical reactions that take place through metabolism produce heat. This heat energy is effectively lost as the animal cools itself. It also represents an energy loss as the energy is derived from the feed. An animal can lose up to 40% of its gross energy intake in this way. Therefore it represents a significant factor in the economic utilisation of food. In all **warm-blooded animals**, maintaining a constant body temperature has a significant impact on the nutritive ratio.

The energy value of feeds

The digestible substances in pastures and feeds are called nutrients. Nutrients can be divided into groups according to the chemical composition of the feeds, see Figure 1.12.

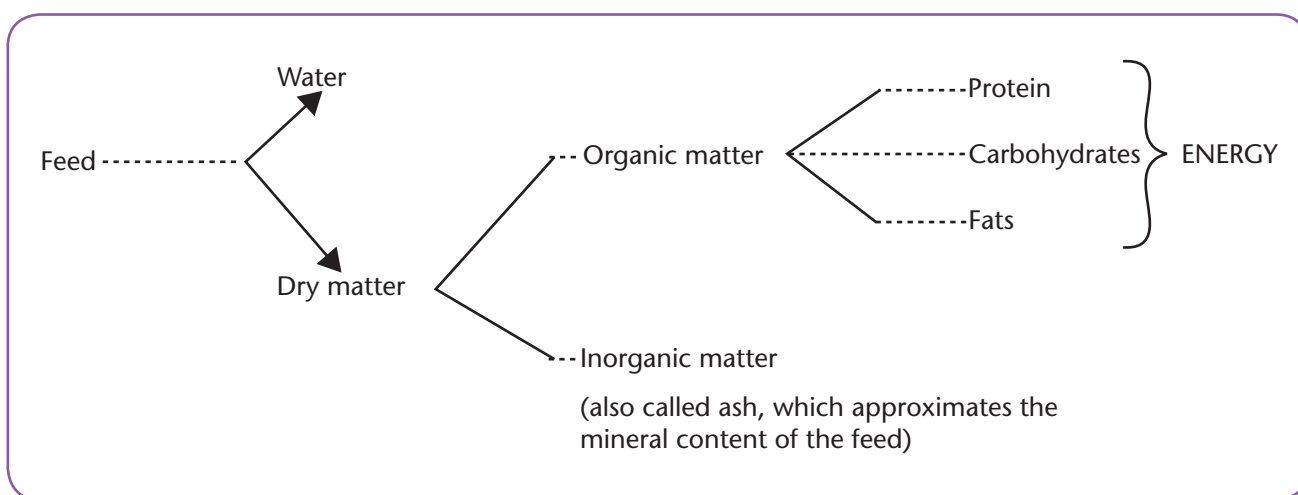


Figure 1.12: Subdivision of nutrients according to the chemical composition of feeds

Proteins, carbohydrates and fats are energy sources in any diet. Fats are the richest source of energy. The Weende analysis system is used in laboratories to analyse feeds. It indicates the following six subdivisions:

- Moisture (water)
Dry matter (DM) = feed minus moisture
- Total ash (TA)
TA = feed minus moisture minus organic matter
- Crude protein (CP)
 $CP = \text{Nitrogen content (N)} \times 6,25$, since most proteins have a constant N-content of about 16%
- Ether extract (EE)
Fats, oils and waxes
- Crude fibre (CF)
That portion of the carbohydrates that is relatively difficult to digest (insoluble portion after boiling in acid and alkali)
- Nitrogen-free extract (NFE)
Easily digestible carbohydrates, for example, sugar

The purpose/aim of calculating the energy value of feed

Through calculating the energy value of feed, it becomes possible to determine the approximate quantity of feed that any animal requires in terms of the number of kilojoules per kilogram of feed – as influenced by the body mass and function of the animal.

Schematic representation of feed energy flow

High energy content in a ration ensures high production. For example, the growth rate of animals in a feedlot is directly proportional to the energy content of the ration. An energy deficiency results in mass loss. Energy intake is limited in situations where the availability of dry matter is restricted. The different measures of feed energy and the relationships between them can be summed up in a feed energy flow diagram.

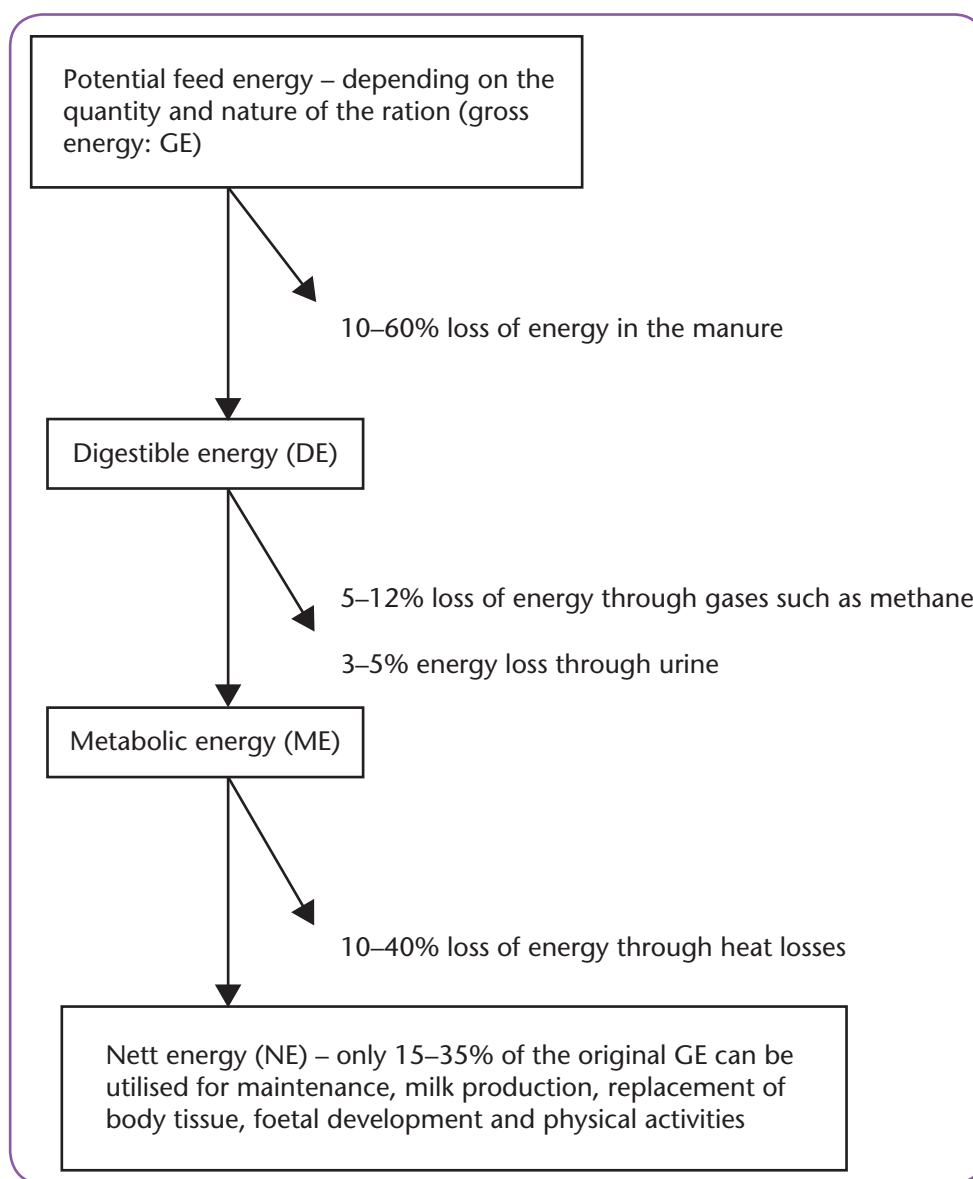


Figure 1.13: A feed energy flow diagram

Calculation of feed energy flow and interpretation of the results

Calculation of the energy flow

When a substance is burnt, the oxidation products are released as CO_2 , H_2O and other gasses, as well as energy. This is regarded as the gross energy of feeds. The energy release from different kinds of feed is as follows:

Carbohydrates	17,2 kJ/gram
Fats	39,6 kJ/gram
Proteins	23,7 kJ/gram

Figure 1.13 illustrates how energy loss occurs from the gross energy value of feed. We can say that not all gross energy is utilised by the body. From the gross energy, loss of energy takes place through the faeces,



urine and the gaseous end-products of digestion. The total energy losses through the faeces, urine and gasses are deducted from the digestible energy, which leaves us with the metabolic energy.

By far the greatest energy losses are those which occur in the faeces, as a result of the non-digestion of certain nutrients.

Energy is also lost through body heat. The chemical reactions that take place in each living cell of a living organism produce heat. This leads to a continual heat loss by the body which varies from 25 to 40% of the gross energy intake.

With regard to food utilisation, it is economically important to keep domestic animals in shelters during spells of cold weather to minimise heat loss. Under these conditions, feeds with a high fat content should be used. Feeds such as oil seeds, which have a high energy value, should be included in the rations.

Interpretation of feed energy flow calculations

The following table gives the energy required (in a diet of dry matter) by medium-frame steer calves:

Daily gain (kg)	Metabolisable Energy (ME) MJ/kg	Maintenance (NE _m) MJ/kg	Gain (NE _g) MJ/kg	Total Digestible Nutrients (TDN) %
Medium-frame steer calves (140 to 450 kg)				
0.2	8.2	4.6	2.3	54.0
0.7	9.6	5.9	3.5	63.0
1.1	11.2	7.3	4.7	73.5
1.4	12.8	8.8	5.9	85.0

High energy content in the ration ensures high production. The growth rate of animals in a feedlot, for example, is directly proportional to the energy content of the ration, to an optimum of about 72% TDN (90% DM), above which the growth rate could decline.

An energy deficiency results in mass loss. When intake is restricted because insufficient dry matter is available, energy intake is limited.

Note: Various systems, and approaches, are used to express the energy requirements of farm animals, and the energy value of feeds. A system which is widely used is the TDN system, in which requirements are expressed as kg/day, or as a percentage. More advanced systems are the ME (Metabolizable Energy) and the NE (Net Energy).

Nutritive ratio (NR)

The concept of nutritive ratio

The nutritive ratio (NR) of feed is the ratio between the digestible protein in a ration of a feed and the digestible non-nitrogen compounds. The NR of a feed is one of the various concepts used to describe the quality of a feed. The NR gives an indication of the protein content of a feed. The protein content influences the quality of a feed because protein plays an important role in animal growth and animal production.

The purpose/aim of the nutritive ratio in animal feeding

The NR is the ratio between the type of production and loss of heat. Nutritive ratios are used to differentiate the nutritive requirements that are used by the animal for maintenance, growth, reproduction and production. In Table 6, different NRs are compared for different purposes.

The table shows that the ratio narrows for growth, reproduction and milk production in a livestock venture. This means that more proteins are needed during these periods (relative to non-proteins), than are needed for maintenance only. The ratio narrows again during periods of fattening of adult animals; meaning that less protein is needed relative to carbohydrates and fats.

Table 6: Nutritive requirements for maintenance, growth, reproduction, production (milk) and fattening

	Maintenance	Growth	Reproduction	Milk production	Fattening (adult animals)
Nutritive ratio (NR)	1:8	1:5	1:5	1:5	1:10
Digestible protein (DP)	Only for replacement of worn tissues	Protein with a high BV required for muscle growth	Additional protein of high BV	Much protein with a high BV	Only sufficient for maintenance
Digestible non-nitrogen substances (carbohydrates and fats)	Only for maintenance of body mass	Only sufficient for maintenance	Only sufficient for maintenance with addition during last phase of pregnancy	Sufficient for maintenance plus the formation of lactose and butter fat	Large quantities

The NR can thus be used by the livestock farmer to serve as a yardstick to know whether the feed ration serves the goal that he/she wants to achieve.

Calculation of the nutritive value of a feed and the interpretation of the results

Calculation of the nutritive value of feeds

As you know, the nutritive value of a feed is the ratio between the digestible protein in a ration and the digestible non-nitrogen compounds. It is calculated as follows:

If fat is included in the ration, then the fat content must be multiplied by 2,5. If a feed has a TDN content of 60% and a digestible protein content (DP) of 7%, then the percentage of digestible non-nitrogen constituent in the feed will be 53% (60 – 7). The percentage of digestible non-nitrogen substances must therefore be divided by the percentage digestible protein, which gives the second factor in the nutritive ratio:

$$\begin{aligned}
 \text{Nutritive ratio (NR)} &= \frac{\% \text{ digestible non-nitrogen substances}}{\% \text{ digestible proteins}} \\
 &= 1: \frac{53}{7} \\
 &= 1:7,6 \text{ (rounded)}
 \end{aligned}$$



Interpretation of the results

Use a 'high' NR for maintenance and fattening because there is proportionally less protein in the ration. Such a ration will not be suitable for production and reproduction. This because a high-protein ration is required for the production of wool, milk, eggs, etc. For reproduction, a high-protein content in the ration is required as it is used for building the new tissues of the foetus and for the production of milk. A ration with an NR of 1:7,6 is suitable for maintenance and for the fattening of matured animals.

Classroom activity 4

Work alone.

During a digestive experiment, five pigs together ate 250 kg of concentrate with the following chemical composition:

- Dry material – 90,0%
- Crude protein – 12,5%
- Crude fibre – 6,0%
- Nitrogen-free extract – 67,5%
- Ether extract – 1,5%

During this period, the pigs excreted on average of 12 kg manure each with the following chemical composition:

- Dry material – 35,5%
- Crude protein – 6,25%
- Crude fibre – 8,0%
- Nitrogen-free extract – 14,75%
- Ether extract – 2,0%

Calculate the digestive coefficient of the concentrate.

Homework activity 4

Work with a partner.

- 1 You can graze a field of oats at different stages: when it is still young, when it is matured but still green, or when it is ripe. Choose one of the options for each of the following:
 - a) Weaners, when preparing them for the abattoir
 - b) Old cows, to be finished off for the abattoir
 - c) The sheep herd for fat lamb production
- 2 Give reasons for each of your responses to question 1.
- 3 Should you graze or cut and bale your lucerne fields for:
 - a) your dairy cows
 - b) your draught horses?
- 4 Give reasons for your answers to 3. a) and b).

- 5 You are in the middle of a severe drought and the only roughage available is baled wheat chaff. Will you mill and/or pellet this chaff with the addition of urea and/or molasses:
- for your beef cattle herd to survive the drought
 - for your dairy cows for milk production?
- 6 Give reasons for each of your responses to question 5.
- 7 Give reasons why proteins with a high BV must or must not be fed to animals in the following cases:
- Cows in milk
 - Cows in calf (that is, pregnant cows)
 - Growing calves or lambs
 - Laying hens
 - Pigs in milk
- 8 Give two reasons why the BV of milk is so high compared with the BV of wheat.
- 9 Why does the white (the albumen) of eggs have such a high BV?
- 10 When should animals be fed on feed with a high energy value, such as starch? Give a reason for your answer.

Extra practice 4

Work alone.

- 1 A sample of feed contains 77,2% total digestible nutrients (TDN) and 9,7% digestible nutrients. Calculate the nutritive ratio of the feed. (Show all your calculations in your workbook.)
- 2 During a digestive experiment, a cow ate 12 kg hay with a moisture content of 10% and excreted 5 kg manure with a moisture content of 20%. Calculate the digestible dry material content of the hay. (Show all your calculations in your workbook.)



Unit 5: Types of feed – classification of feed, feed flow programme

What you will learn about in this unit

- **types of feed**
 - classification of animal feeds
 - the concept: roughages and concentrates
 - the characteristics of roughages and concentrates
 - the description of different types of roughages and concentrates
 - the schematic representation of different types of animal feeds
 - the functions (importance) of roughages and concentrates
- **subdivision of feeds**
 - the comparison between protein-rich and carbohydrate-rich types of feeds (examples of protein-rich and carbohydrate-rich feeds)
- **supplements to rations**
 - the different ways of supplementing: minerals, vitamins, non-protein nitrogen and growth stimulants
- **planning a feed flow programme**
 - the terminology: feed flow program, maintenance and production ration
 - a brief overview of the Pearson square method (feed formulation)
 - calculation and the drawing of feed requirements using a single Pearson square method
 - the interpretation of the Pearson square results for feed mixtures
 - fodder/feed flow/fodder production planning
 - the importance of fodder flow/fodder production planning
 - basic calculation of a feed/fodder flow program for a group of livestock (number of animals and feed needed over a period)

Let's talk about this unit

A farmer needs to be constantly aware of the supply of balanced nutrition to his or her livestock. This means that he or she must understand the value of the nutrients in terms of proteins, carbohydrates, vitamins and minerals, and how they play their parts in maintaining the livestock and increasing production. The economic questions of how to try to be self-sufficient and how to calculate the costs and benefits of supplementing feed are very important. In this unit, you will learn about the value of supplements and how to calculate the nutrient value of feeds.

What do I know already?



Farmers become very anxious in times of droughts. If the first rains of the season come late, you will find that cattle or sheep farmers will be very worried about the available feed for the animals. They are worried about the feed flow of the farm.

Check myself

What kind of feed is usually purchased by livestock farmers to feed their animals? You may have seen bales of feed being trucked to farms, particularly in the dry western parts of the country. This is a sign that farmers are forced to combat the harsh conditions. But you should also be aware that farmers use expensive supplements such as licks as part of their feeding programmes. This is a sign that the farmers need to take measures to create the best products and not rely only on what is available in the veld, especially during droughts.

Word bank



animal unit (AU):	one animal with a mass of 450 kg, with a dry matter (DM) requirement of 10 kg per day
bulk (in ration):	volume in feed intake
herd configuration:	the numbers of each kind of animal in a given herd – old cows, weaners, etc.
palatable:	food that tastes good and is easy to eat

What I still need to know



Types of feed

Classification of animal feeds

Animal feeds can be classified according to the concentration of nutrients in them. Feeds high in crude-fibre content are called roughages. Feeds with a high concentration of nutrients with little crude fibre are called concentrates. There are also several subcategories. The following figure shows the subcategories:

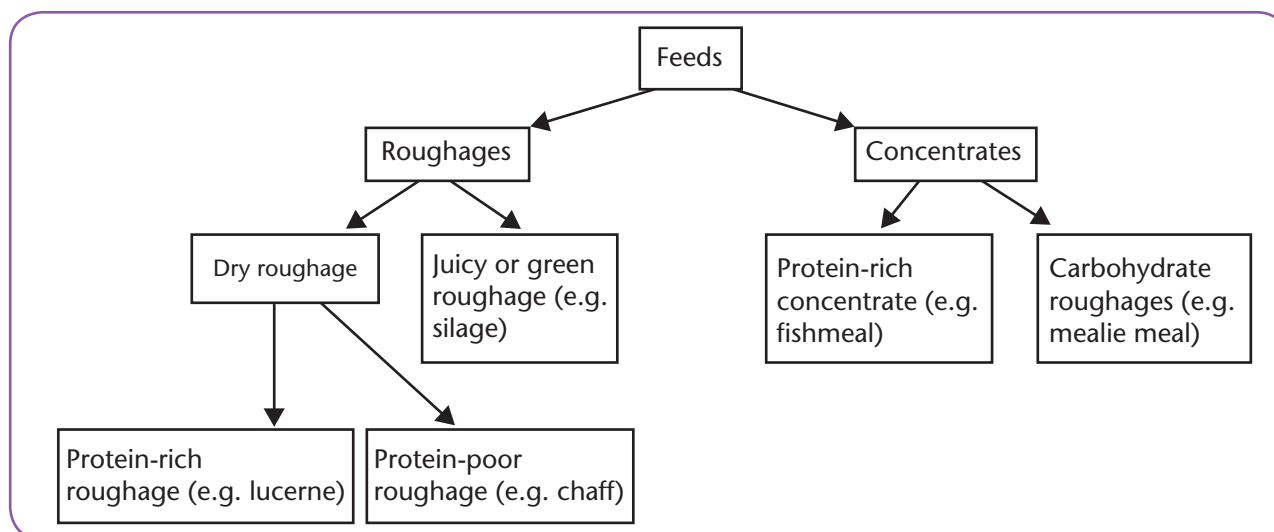


Figure 1.14: Schematic representation of feed types



The concept: roughages, and their characteristics

Roughages have high crude fibre content and are consequently bulky. Per unit of mass and volume they contain very few digestible nutrients (not more than 60%).

In general, roughages have the following characteristics:

- The digestibility of lucerne hay, and therefore its nutritive value, depends on the way in which the lucerne was cut down and baled. Cowpea hay is not as rich in protein as lucerne hay. The fibre of cowpea hay is not as digestible as lucerne hay.
- Maize stalks are a good maintenance feed for ruminants. If maize stalks are cut and baled, their nutritive value will be greater than if they are left exposed to the elements. Oats hay is very **palatable** but has a low protein content.
- Chaff is the straw from cereals and has a low nutritive value. It is good for adding **bulk** to a ration.
- Silage is not roughage in the real sense of the word. This is because it is preserved plant material in a moist form. It is very palatable. The plant material that it was made from determines the nutritive value of the silage.

The concept: concentrates, and their characteristics

Concentrates are feeds with either a high protein content, such as fishmeal, or high energy content, such as maize meal. They have a high TDN, greater than 60%, and so have a high nutritive value. Concentrates are not bulky and are generally very pricey. In general, concentrates have the following characteristics:

- Fishmeal is rich in proteins and minerals, such as calcium and phosphorus. Because it is rich in essential amino acids, it has a high BV (biological value).
- Oil-cake meal is a by-product of the oil-seed industry. Its BV is not as high as fishmeal. It is, however, very suitable for young growing animals.
- Maize meal is very rich in carbohydrates in the form of starch. It is low in fibre and so is very digestible. It has a low protein content.
- Oatmeal contains digestible proteins and fats. Because of the hard cover around the seed, it is not very digestible for non-ruminants.

The functions (importance) of roughages and concentrates

Functions (importance) of roughages

- Large farm animals are partly dependent on roughages for bulk in their ration.
- Roughages are the cheapest source of feed when they are of good quality.
- They provide bulk in the ration.
- Roughages stimulate rumen development in young ruminants.
- Dry roughages in the rumen will prevent bloating in ruminants.

Functions (importance) of concentrates

- Concentrates are used to balance roughages by providing more protein and energy for the animal.
- Pigs and fowls are fed concentrates because they cannot digest roughages.
- Intensive meat and dairy production animals need to feed on concentrates.
- Concentrates are used for fattening animals for slaughter.

The different types of roughages and concentrates

There are many types of roughages and concentrates that can be used for animal feeds. In this unit, we are going to look at the properties of the different types of roughages and concentrates.

The different types of roughages – their properties

Lucerne hay as an example of protein-rich roughage

The nutritive value of lucerne hay varies depending on the hay-making process. In general, lucerne hay has these properties:

- It is rich in calcium. A ration consisting of lucerne hay must have a phosphate supplement in order to obtain an ideal Ca:P ratio.
- Lucerne hay contains many elements, for example cobalt, iron, calcium, potassium and molybdenum, that are important in the feeding of ruminants. These micro-elements stimulate the micro-organisms in the rumen.
- Lucerne meal has a higher nutritive value than lucerne hay and because it has a lower fibre content, it can be included in pig rations.
- Lucerne is deficient in the sulphur-containing amino acids methionine and cysteine. These amino acids are important for wool production. As a result, lucerne can be fed to wool-producing sheep only if it is supplemented by feeds containing these amino acids in the correct proportions.



Figure 1.15: Bales of lucerne hay

Maize stalks as an example of a protein-poor roughage

Although maize is planted for seed production, the dry stalks (crop-rests), leaves and cobs can be utilised as roughages in animal feeds. The properties of maize crop-rests can be summarised as follows:

- Maize stalks that are exposed to rain are worth less than those packed in stacks indoors or covered by plastic sheeting.
- Maize stalks are a good maintenance feed for ruminants during the winter.
- The heat production during the digestion of maize stalks keeps the animals warm.
- Maize stalks supplemented with urea and molasses are very palatable and nutritious.
- Maize stalks have a low nutritive value and should be supplemented with proteins, minerals, vitamins and energy by means of concentrates.

Silage as an example of green (or moist) roughages

Silage is made from different sources. Maize plants are the most popular source. Grain and green lucerne hay are also popular. The properties of silage can be summarised as follows:

- Silage should be fed together with dry material in the ratio of 3:1.
- Because of the high moisture content and low protein content, silage should be utilised as a supplementary feed for animals.



- Silage must be supplemented with protein-rich feeds for growth and with carbohydrate-rich feeds for fattening purposes.
- Silage plays an important role as animal feed during the winter periods.
- The carbohydrates in the plant material will be fermented by microbes to form lactic acid with a drop in pH to 4,2.
- Silage with a low pH can be kept for unlimited time under anaerobic conditions.
- Good-quality silage is very palatable and can be fed to cattle and sheep.
- Certain crops, such as maize and lucerne with a high yield of green material per hectare, can be utilised for silage with great success because moisture and volatile acids that contribute to the nutritive value are lost with exposure to air.
- Poor-quality silage can cause digestive problems in ruminants.
- Carbohydrate-rich material must be added to protein-rich material when silage is made.
- Silage increases the digestibility of other feeds in the animal's ration.

The different types of concentrates – their properties

Fishmeal as an example of a protein-rich concentrate

Fishmeal has a high TDN, about 72%, and is rich in proteins (about 48,5%) and minerals (about 20%). The properties of fishmeal can be summarised as follows:

- It is one of the cheapest protein supplements in South Africa.
- The protein in fishmeal has a high BV and is rich in scarce amino acids.
- Fishmeal is a good source of vitamins A, D and B12.
- Fishmeal is an excellent protein supplement for young, growing animals and high-producing non-ruminants such as pigs and fowls.
- Fishmeal has a high nutritive value for pigs, fowls and young calves. Calf starter meals must contain at least 20% animal protein.
- If fishmeal is used in the right quantities, so as to balance the ration, it does not give a fishy taste to the end product.

Maize meal as an example of a carbohydrate concentrate

All grains fall into this group. We will focus on the properties of maize meal because it is so widely used in intensive livestock production. It can be summarised as follows:

- Maize is the tastiest grain for farm animals because of its high fat content.
- Maize is one of the best feeds for all types of animals, if it is supplemented with amino acids.
- Animals that are fed only white maize must also be fed good hay as a vitamin A supplement.
- Because of the oily nature of the fat in maize, it must not be fed in large quantities to pigs, as it produces soft fat and an oily carcass.
- Fishmeal is an excellent supplementary feed for maize, because fishmeal supplements the deficiency of certain amino acids in maize.

Subdivision of feeds – comparison between protein-rich and carbohydrate-rich feeds

The livestock farmer must make different choices of animal feed in order to achieve his/her aims for livestock production. In this unit, we give a brief summary of the suitability of commonly used protein- and

carbohydrate-rich feeds. From this summary, different feeds can be compared for their appropriateness to the goal which is set for the venture, be it the production of broilers, bacon production, milk production, etc.

The suitability of different protein-rich feeds

Lucerne hay as a protein-rich roughage

Suitability for growth

Lucerne hay contains digestible proteins. Digestible proteins increase the growth of ruminants.

Suitability for fattening

Lucerne hay has a high quantity of protein and a low quantity of carbohydrates. A small quantity of energy-rich maize meal mixed with lucerne makes an ideal ration for the fattening of ruminants.

Suitability for production

Lucerne hay is most suitable for the production of protein-rich products from ruminants. Cows produce very well on lucerne hay alone.

Supplement for energy

Lucerne hay can be served as the roughage for horses and mules that work hard. However, it must be supplemented with energy-rich concentrates.

Fishmeal as a protein-rich concentrate

Suitability for growth

As a result of its high protein content and its high BV, fishmeal is well suited for the growth of young animals.

Suitability for fattening

Fishmeal is too expensive for fattening purposes and it gives an unpleasant taste to the product when added in high quantities.

Suitability for production

It is suitable as a protein supplement for the rations of cattle, sheep and pigs. It must, however, be restricted as a result of the tastes given to the end product.

Suitability for energy

Fishmeal is very expensive and its utilisation as a source of energy should be handled with care because of its cost and its potential for giving a fishy taste to the end product.

Oil-cake meal as a protein-rich concentrate

Suitability for growth

It is well suited for the growth of young animals. This is because of the high protein content and a high BV.

Suitability for fattening

It is too expensive for fattening purposes, and it can lead to soft bacon in pigs.

Suitability for production

It is a suitable protein supplement in the rations of cattle, sheep, pigs and horses.

Suitability for energy

It is well suited for energy purposes because it has a high energy value. As it is relatively expensive, it must be used in small amounts.



The suitability of different carbohydrate-rich feeds

Maize meal as a carbohydrate-rich concentrate

Suitability for growth

It is not suitable for young growing animals because of its protein deficiency and relatively low BV, which do not aid growth or reproductive capacity. It is suitable for fattening adults for meat production.

Suitability for fattening

Maize meal is rich in energy and therefore suitable for fattening purposes. It may, however, cause soft body fat in pigs.

Suitability for production

It must be supplemented with proteins for the production of products rich in proteins, for example eggs and milk.

Suitability for energy

It is a feed rich in energy.

Oatmeal as a carbohydrate-rich concentrate

Suitability for growth

It is more suitable for growth than maize because of its higher protein content. However, the BV is not good and must be supplemented.

Suitability for fattening

Although it is less energy-rich than maize, it is still effective. It forms soft bacon in pigs.

Suitability for production

It must be supplemented with proteins to produce protein-rich products, such as milk and eggs.

Suitability for energy

It is well suited for horses.

Conclusion

If the farmer has set a goal for the livestock production unit, such as growth or fattening, he or she can make a choice among the different feeds. This choice will also be influenced by availability of the feed and the cost per unit of the different feeds.

Supplements to rations

Especially under intensive livestock production, there will be deficiencies in the daily feed ration of animals. There may be deficiencies in amino acids, minerals or vitamins. These deficiencies may lead to a lowering in production, illness and, in the worst case, to death. For this reason, the supplementing of certain nutrients to the ration of livestock is important.

In Africa it is believed that one or two crops should be planted which can be used if natural grazing becomes short. Elephant grass is very easy to grow and produces a great amount of leaves. Trees that can be grown as supplements to ration are the willow, poplar and the horse tamarind. Besides planting crops to supplement feeds, the making of hay is also a tradition in Africa. Weeping Love-grass is one of the best grasses to make hay from, to supplement to the sparse winter grazing.

Supplementing minerals

Minerals are supplemented using different methods.

Mineral licks

Licks usually consist of a salt (such as calcium phosphate) or bonemeal, and small quantities of micro-elements. It is made freely available to ruminants. The intake of the lick is controlled through the concentration of salt in the lick. The composition of licks must be clearly indicated. A winter lick supplements protein and energy deficiencies with urea and molasses. The ruminant is then enabled to make use of the available dry winter grazing more efficiently. This is particularly true of sour veld.

Drinking troughs

Soluble mineral salts are added to the drinking water of the herd. This is done at a concentration of $\pm 2 \text{ kg}/5\,000 \text{ l}$ water. Some problems with this method are:

- it is often difficult to keep this concentration constant
- algal growth can occur because of the nutrients in the water.

Supplementing rations

Where animals do not utilise natural grazing, but instead receive a balanced ration, all the required minerals are mixed in a concentrate mixture. This is the case in intensive livestock production of broilers and pork, and beef cattle in feedlots.

Dosing

Animals may be dosed with minerals. Because this is labour-intensive, a method should be followed that releases ions in the rumen of a ruminant over a period.

Injections

In the case of a calcium deficiency, calcium may be injected into the bloodstream of dairy cows. This method may also be used to supplement magnesium and iron.

Supplementing vitamins

Vitamin A supplements are important for ruminants. Vitamin D supplements are important for animals kept indoors. It is important to supplement most vitamins when keeping pigs or fowls. Methods of supplementing are injections and supplementary rations.

Injections

Vitamin deficiencies are supplemented by intramuscular injections. A deficiency of vitamin A occurs in ruminants during droughts and severe winter conditions. Supplementing it is essential.

Supplementary rations

The ration of animals such as pigs or poultry should be supplemented with vitamins to supply the minimum requirements.

Supplementing non-protein nitrogen

Non-protein nitrogen is usually supplemented in the form of urea. The following methods are used:

- 2 kg urea and 20 kg molasses are dissolved in 12 l of water and mixed. This mixture is then sprayed over natural grazing.



- Licks containing urea and molasses can be provided to the herd.
- Urea should be included in the concentrate mixtures for animals in intensive production conditions, such as dairy cows.

Supplementing growth stimulants

Growth stimulants are added to rations to promote growth or production in that animal. There are a large number of stimulants, such as:

- antibiotics – used to improve the growth of chickens
- hormones – used to stimulate growth and fatten livestock; for example, hormones are implanted in the ears of oxen during fattening for the market
- thyroid regulators – influence the secretion of thyroxin by the thyroid gland; thyroxin also plays an important role in the growth and fattening of animals
- tranquilisers – cause animals to be calm. When animals are calmer they eat more and gain mass more rapidly.

Planning a feed flow programme

The aim of planning a programme for feeding is to match the amount of feed that the farm can produce (the feed production capacity) with the number of animals the farm can hold (the animal production system). If the feed supplies match the feed demand on the farm, then the farmer will be self-sufficient. In other words, the farmer will be able to provide feed for livestock throughout the year, and will not need to buy additional feed for them. This minimises the cost of feeding.

Terminology relating to feed flow programmes

You need to distinguish between feed types that will maintain livestock in difficult conditions, and feed types that will encourage production when conditions are favourable.

Feed flow programme

A feed flow programme is a way of measuring the requirements of the farm's livestock and balancing this with the farm's ability to produce suitable crops as nutrients.

Maintenance ration

The quantity of feed required to maintain an animal while it is unproductive is called a maintenance ration. This depends on the body mass and type of animal. When an animal receives a maintenance ration, the body mass will remain constant. Roughly half the feed an animal eats is required for maintenance.

Production ration

In addition to the feed required for maintenance, certain nutrients are required for the production of various products, for example eggs and meat. The animal uses the feed that is required in addition to the maintenance ration for production. This additional feed is known as the production ration. The quantity of a production ration is determined by the nature of the product.

The Pearson square method – overview

Livestock production aims for the efficient transformation of feeds into a specific product, for example meat or milk. This can be achieved only if the livestock is fed a proper, balanced diet. There are many ways to balance a diet. A well-known method of balancing diets is the Pearson square method.

The Pearson square method is a way of balancing rations, which works best when there are only two ingredients that need to be mixed. There are numbers that appear in and around the square – the most significant number being the one that appears in the centre of the square. This number represents the amounts of a specific nutrient required by an animal (it could be a mineral, vitamin, amino acid or crude protein).

To use the Pearson square method, you begin with the DM and TDN and then supplement with appropriate concentrates by using the Pearson square. Thereafter the digestible crude protein (DCP) is checked. A shortage in protein, for example, should be supplemented with a nitrogen lick.

Calculation and the drawing of feed requirements using a single Pearson square method

A farmer has maize and soya beans available for compiling a balanced diet for laying hens. Laying hens need 20% protein. The maize has a protein content of 9% and the soya beans a protein content of 40%. How much of each feed should you give to the hens? Follow the instructions below to find out.

1. Draw a square. Divide the square into four triangles by drawing a line from the top left-hand corner to the bottom right-hand corner, and from the top right-hand corner to the bottom left-hand corner.
2. In the centre, where the two lines cross, write down the amount of protein required. The amount in this case is 20%.
3. Write the protein content of maize and soya beans as illustrated below:

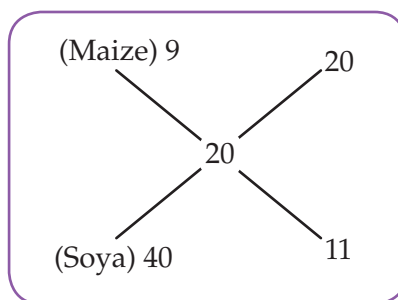
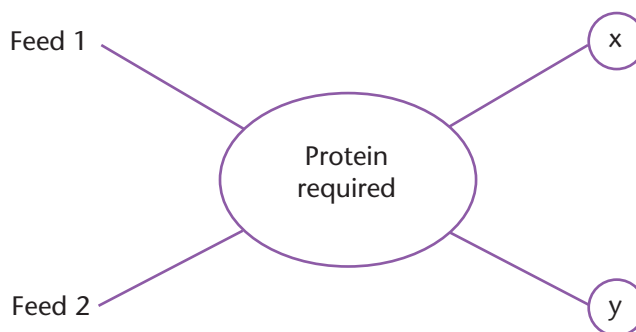


Figure 1.16: The Pearson square method

4. Subtract the percentage of protein content of the feeds from the required percentage of protein content. Write the answers in the opposite corners.

The percentage of protein content in maize is 9, and $20 - 9 = 11$. The percentage of protein in soya is 40, and $40 - 20 = 20$ (always subtract the smaller number from the larger one, as you cannot add negative amounts of protein to the feed). This means that 20 units of maize to 11 units of soya beans will ensure a 20% protein value.

5. Here is the formula for calculating the Pearson square:





$$\% \text{ Feed 1} = \frac{x}{\text{protein required}} \times \frac{100}{1} = \%$$

$$\% \text{ Feed 2} = \frac{y}{\text{protein required}} \times \frac{100}{1} = \%$$

6. The following calculations are done to find out the percentage of each ingredient of the diet:

$$\begin{aligned} 20 + 11 &= 31 \\ \% \text{ maize} &= \frac{20}{31} \times \frac{100}{1} \\ &= 65\% \\ \% \text{ soya beans} &= \frac{11}{31} \times \frac{100}{1} \\ &= 35\% \end{aligned}$$

The interpretation of the Pearson square results for feed mixtures

Feed mixtures are expressed per 100 kg as it makes the percentage conversion easier. So we can see that a mixture of 35 kg of soya beans and 65 kg of maize would result in a balanced diet. One can also supplement this diet with vitamins and minerals. For example, you could add calcium and phosphorus or even table salt. The salt can be added to regulate the intake of the concentrated feed because cattle will eat less of the salty supplement.

Fodder/feed flow/fodder production planning

The importance of fodder flow/fodder production planning

The farmer can provide feed throughout the year (without having to buy additional feed) by programming the flow of fodder (fodder flow). This will help to minimise the cost of feeding. Often more than one livestock enterprise is practised on a single farm. The seasonal demands on the available feed will depend on the combination of livestock enterprises on the farm. Seasonal forage demand will depend on:

- the date of calving or lambing
- the weaning date
- the ratio of dry to breeding animals
- the age at which animals are sold
- the stocking rate (the size of the herd per property).

To match the size of the herd on the farm to the feed production capacity of the farm, you must first establish what the expected forage production capacity of the property is likely to be. In other words, calculate how much fodder the farm will be able to produce. From this, you can work out how many animals the fodder can feed. This will give you the number of animals (the **animal units**, or AU) that the property is able to support without having to buy additional feed.

Basic calculation of a feed/fodder flow program (for a group of livestock)

The farmer must do a survey of the property's fodder-production potential. Such a survey involves an assessment of the seasonal availability of feed from the natural veld. It should assess both yield and quality. It should also include an assessment of the areas of land best suited to the production of

different fodder crops. The objective is to produce all the feed requirements for the farm on the farm. This way, the farmer can minimise his or her expenses. There are three steps in matching the supply with the demand for fodder.

- Step 1:** Make an estimate of the **herd configuration** from month to month, i.e. how the numbers of each age group change from month to month. Animals of different mass have a feeding requirement that can be calculated from tables provided by sources such as *Veld & Pasture Management in South Africa* by MN Tainton. The number of AU equivalents for each class is then calculated. The AU equivalents for the different classes are then added and divided by the number of AU equivalents that the farm can accommodate, i.e. the farm's carrying capacity.
- Step 2:** The configuration of the livestock enterprise must now be corrected. This is done in relation to the total digestible nutrient (TDN) and digestible crude protein (DCP) requirements of the different classes of animals on the farm. A survey of the farm's fodder production potential should be done. This includes an assessment of the availability of feed from the veld per season. A further survey should be done of the areas of land best suited for the production of different forage crops. It then becomes possible to match the fodder supply from a combination of crops with the feed requirements of the livestock enterprise on a monthly basis.
- Step 3:** The programme of fodder demand and fodder supply can now be assessed in detail. The herd is divided into their separate groups. For example, they would be grouped as bulls, cows, calves, weaners, etc. The seasonal requirements for each group are determined separately. These requirements include both the dry matter (DM) and the total digestible nutrients (TDN). The requirements of feed for each group are then combined to give a total feed requirement for each month of the year.

Actual calculation of the fodder flow programme

The total annual fodder supply has to be calculated according to the scale of the enterprise. For example, if the annual fodder supply is 1 250t DM and the 100-cow beef unit consumes 750t DM then 166 cows and their followers can be fed. To refine the calculation, the herd structure should be determined, and then the monthly fodder intake of different groups or subclasses of animals can be calculated. This calculation is done based on the relationship between metabolic mass (mass to the power of 0.75 i.e. $W^{0.75}$) and feed intake. For example, a 450-kg animal consumes the following amount of dry matter each day:

$$\begin{aligned}\text{Fodder intake per day (kg DM)} &= 0.1 \times W^{0.75} \\ &= 0.1 \times 450^{0.75} \\ &= 0.1 \times 97.7 \\ &= 9.77 \text{ kg DM}\end{aligned}$$

Where DM = dry matter, and W = mass.

A fodder flow programme should be compiled:

- Enter the dry matter requirement of the herd, by month, by growth, into the programme.
- Enter the total area of the property under irrigation, plus dry land cropping, plus dry land pastures.
- Enter the areas of irrigable land and dry land for each forage species, indicating the forage production of these crops per hectare.
- Balance the production of crops listed in the programme against the animal requirements, month by month.
- Allocate conserved foods (hay and silage) in appropriate quantities to those months in which there is a deficit of grazing dry matter (DM).



The example of a fodder flow programme given below is taken from *Veld and Pasture Management in South Africa* by MN Tainton.

	Area (ha)			Months													Cost	
	Total	Dry-land	Irrigated	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	DM total (ton)	(R/ton)	Total
Livestock DM requirement				91	95	95	94	96	100	94	92	84	85	85	87	1098		
Forage type grazing																		
Veld grazing	100	100		15	20	30	20	18	15	5					5	128		
Kikuyu	40	25		12	25	25	33	22	20	10						147	20.00	2,940.00
Fescue-clover		15		25	25	20	13	23	30	15					15	166	8.50	1,411.00
Italian ryegrass	30			30	25				14	25	30	15	10	15	25	189	18.00	3,402.00
Kikuyu			15	12	20	24	30	24	22	13	6					151	14.00	2,114.00
Total Grazing				94	115	99	96	87	101	68	36	15	10	15	45	781		
Total Grazing less requirement				3	20	4	2	-9	1	-26	-56	-69	-75	-70	-42	-317		
Forage type - conservation (dryland)																		
Eragrostis (hay)		10			25		30			25						80	25.35	2,028.00
Maize (silage)	35	15	15					200								200	16.40	3,280.00
Japanese Radish		10	10								50					50	22.10	1,105.00
Total area	205	175																
Utilisation of conserved feeds																		
Eragrostis (hay)										5	16	12	12	12	10	67		
Maize (silage)											40	40	46	42	32	200		
Japanese Radish												17	17	16		50		

Interpretation of the calculations

The data in the table above can be used to assist in the selection of the forage species which can best help to balance feed requirements of the herd with forage production on the farm. The objective of a fodder flow programme is to match the feed production (potential) of the farm to a livestock production system. The ideal is to keep feed costs for the livestock enterprise to the minimum. This entails a matching of feed supply with food demand. Both supply and demand can be modified in practice, at least within reasonable bounds, by selection of well-adapted forage species, use of fertiliser, irrigation of artificial pasture, conservation of forage, etc.

Budgeting for feed supply

With a cropping and pasture plan in place, the feed resources should be allocated to the different blocks of animals. It must be done in such a way that the proposed feeding programme is practically and financially feasible. Allocation of quality feeds must be made in such a way that it favours the highest producers at their critical periods. Concentrate feeds can also be introduced at this stage. Budgeting for cattle's feeding requirements should be done as follows:

- Quantity: The dry matter (DM) and the digestible crude protein (DCP) and the total digestible nutrients (TDN) of each group of animals per month.
- Allocation: Allocate feeds to each group according to their requirements and available feeds. If feeds are insufficient, a feed of higher TDN must be incorporated and should include a concentrate as a supplement to the ration.

You can then determine the quantities of feed required, and their costs, for each group per month. After that, you can calculate the cumulative quantity of feed required with the total costs involved.

At the same time calculate the financial returns from the livestock enterprise. To achieve this you need to describe the proposed herd, and include the levels of performance. Note that these calculations are based on the number of AU that the farm can support.

Classroom activity 5

Work alone.

- 1 Identify the type of feed according to the description in each case:
 - a) is very palatable and usually used in dairy production
 - b) has a high BV and is rich in scarce amino acids
 - c) a very tasty grain
 - d) a good maintenance feed for ruminants
 - e) hay, rich in protein
 - f) a protein-rich concentrate
 - g) a concentrate, well-suited for horses
- 2 Give the way in which the following minerals are supplemented:
 - a) licks (minerals)
 - b) vitamins
 - c) growth stimulants



- 3 A farmer has maize and fish meal available for compiling a balanced diet for the laying hens. Laying hens need 20% protein. The maize has a protein content of 11% and the fish meal has a protein content of 35%. How much of each feed should the farmer give to the hens?
- 4 Summarise the three steps in the planning of a fodder flow programme.

Homework activity 5

Work alone.

- 1 Write a paragraph explaining how a livestock farmer can modify the feed supply on a property. Use the following key concepts:
 - using different varieties of fodder plants
 - stimulating fodder production artificially
 - conservation of fodder
 - management practices of livestock
 - feeding and supplementing natural pastures
- 2 Explain how the following factors will influence the demand for fodder over the different seasons of the year:
 - a) calving/lambing date
 - b) weaning date
 - c) number of breeding animals
 - d) size of herd (stocking rate)
- 3 Describe the correct procedure for a survey of the fodder production potential of a property.
- 4 Feeds are divided into two groups. Name the two groups and give an example for each group.
- 5 A farmer has maize and soya beans available for compiling a balanced diet for the laying hens. Laying hens need 20% protein. The maize has a protein content of 9% and the soya beans a protein content of 40%. How much of each feed should you give to the hens? (Show all your calculations in your workbook.)

Extra practice 5

Work with a partner.

In this unit, you learnt about the nutritional components for animal production. Use this knowledge to complete the table below. Column 1 gives a list of different farming situations. For each of these situations, choose the most appropriate feed or feeds and/or lick, and write this in column 2.

In column 3, give a reason for each answer.

1. Situation	2. Type of feed and/or lick supplement	3. Choices and reasons
Laying hens under intensive production conditions (lay batteries)		
Broiler production under intensive conditions (broiler house)		
Dairy cows under intensive conditions (milking parlour with crib feeding)		
Supplementary ration for sheep during drought		
Supplementary ration for beef cattle during dry season		
Fat lamb production under intensive conditions (feedlots)		
Beef production under intensive conditions (feedlots)		
Preparing rams for the national agricultural show		
Keeping draught horses in a stable		

Animal production

What you will learn about in this topic

- animal production systems
- examples of intensive farming production
- examples of extensive farming production
- animal shelter/protection/housing
- intensive animal production systems
- behaviour of farm animals
- handling of farm animals



Let's talk about this topic

The farmer or farm manager has to consider many factors to rear livestock successfully. This is because the successful production of domesticated animals does not only depend on the inherited characteristics of the animals. The animals have to be handled correctly. Correct handling should include facilities that house or shelter the animal. These facilities should be the appropriate size for the animal and vary depending on the intensity of the livestock production enterprise.

Unit 1: Animal production systems

What you will learn about in this unit

- **animal production systems**
 - description and comparison of intensive and extensive animal production systems
 - the differences between small-scale/subsistence and large-scale/commercial farming systems
- **examples of intensive farming productions**
 - factors to increase animal production under intensive farming (broiler production):
 - nutrition/feeding
 - environment
 - reproduction/breeding
 - general production enterprise management
- **examples of extensive farming productions**
 - factors to increase animal production in extensive farming (beef production):
 - nutrition/feeding
 - environment
 - reproduction/breeding
 - general production enterprise management

Let's talk about this unit

We have a **dualistic** agricultural industry in South Africa. On the one hand, we have traditional subsistence farming and on the other, we have highly sophisticated commercial farming.

What do I know already?



In Grades 10 and 11 you were introduced to and learnt to appreciate the different systems of farming in South Africa. You might have noticed that an emphasis was placed on indigenous farming systems. In this topic, you will explore both large-scale and small-scale farming systems, and learn to appreciate the importance of small-scale farming systems and indigenous farming methods.



What does the concept of the 'emerging farmer' mean to you? Do you understand the differences between subsistence farmers, commercial farmers, intensive and extensive farming systems and the different scales of farming: small, medium and large.

Word bank

ABC

dualistic:	made up of two philosophies; consisting of two parts
environment:	surroundings; conditions under which humans, animals or plants live
hybrid:	result of cross-breeding
incubator:	an apparatus within which eggs are hatched artificially
tethered:	when animals are tied to a rope while grazing; this restricts their movement to the length of the rope

What I still need to know



Animal production systems

Description and comparison of intensive and extensive animal production systems

Different livestock breeds have developed over time through various selection methods and selective breeding. These different breeds have been developed in order to survive better in specific **environments**. By using a well-planned breeding programme, the farmer can make it easier for a plant or animal to survive in a specific environment. In the case of livestock, farmers can breed animals that are better adapted to differences in temperature, rainfall, humidity, disease, etc.

Extensive livestock production occurs when animals are kept under the natural conditions of their surrounding environment. Sometimes animals are kept under artificial production conditions, for example in a sheltered kraal, chicken run, pigsty, milking parlour or stable. This is called intensive livestock production. Examples of intensive livestock production are chickens kept in a broiler, dairy cows in a dairy shed and cattle or sheep in a feedlot. Animals that are kept under intensive production conditions are not affected by the environment. Instead, the farmer creates a suitable artificial environment by, for example, heating or cooling the building, closing the doors, controlling the light levels, and inoculating against diseases.

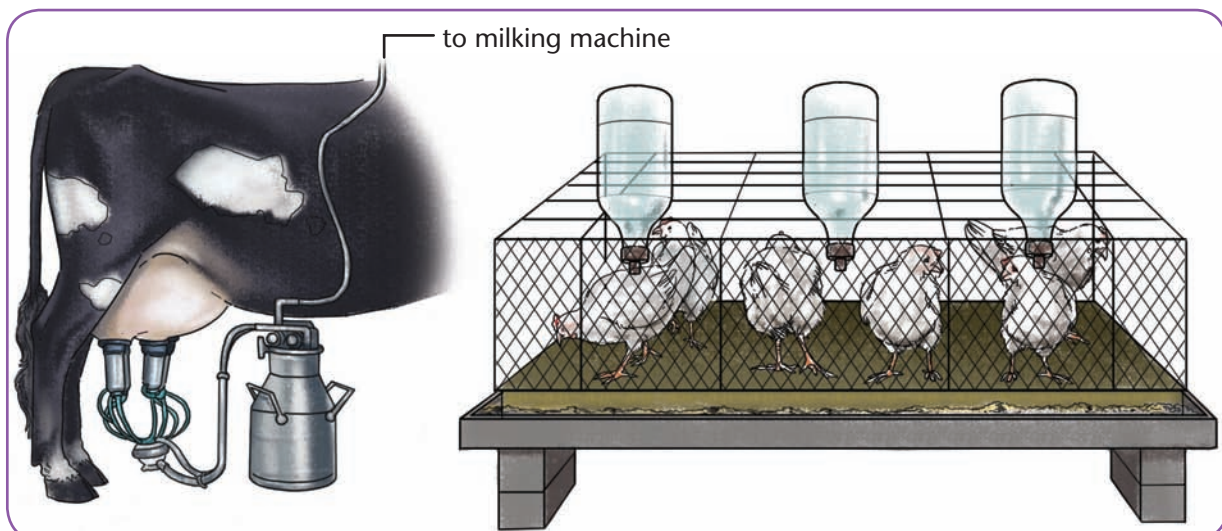


Figure 2.1: Intensive production systems

Intensive livestock production

The livestock groups and breeds listed in the table below are usually kept under intensive conditions. The products that are obtained from the animals are also listed in the table. These animals seldom form part of the grazing stock. They are part of an intensive livestock production unit, and are fed intensively for the production of agricultural products. These animals do not depend on the natural veld and can be kept in any suitable place.

Table 1: Livestock groups and breeds

Livestock groups	Examples of breeds	Products/uses	Possible area of production
Dairy cattle	Jersey Friesland	Butter Milk	Near cities Near cities
Poultry	White Leghorn White Australorp Cornish Game	Eggs Meat (broilers) Meat	Anywhere In broiler houses or batteries near cities
Pigs	Large White SA Landrace	Pork Bacon	Near cities Near cities
Horses	Percherons Clydesdale American Saddle Arab	Draught horse Draught horse Riding horse Riding horse	In rural areas In rural areas Near cities Near cities

Extensive livestock production

There are several breeds that are used for extensive farming in South Africa. Indigenous African breeds and British breeds are all used for extensive livestock production. South African farmers have also created cross-breeds between European and African cattle. These cross-breeds are well adapted to South African conditions, and produce more meat than indigenous breeds. It is very important for a farmer to select the right breed of livestock for the region in which he or she farms. The animals should be well suited to the natural environment of the area for the farm to operate successfully.

It may be wise for a farmer to choose the same kind of livestock as other farmers in the region. Provided the farmer has some knowledge about animal breeds, he or she would be able to upgrade his or her stock by breeding the local stock with a superior breed.

A farmer should never try to rear a kind of animal or breed that is not suited to the environment of the region. For example, rearing Dorset Horn sheep, which prefer mild temperatures, in the hot Karoo region would be a disaster.

A farmer can change the breed of stock at any time and can even decide to replace the kind of livestock with a totally different one. He or she cannot, however, change the veld or the climate of a region, i.e. the rainfall, humidity, average winter temperatures, etc.

Choosing the best kind of livestock and breed for your local environment

It is very important to select the right kind of animal. It is expensive and inefficient to try to keep breeds that are not suited to the local environment. Money would be wasted on things such as protection from the weather, heating, disease and parasite control. The more a farmer spends on sheds, barns or other forms of protection, the less profit he or she has to take home at the end of the month.